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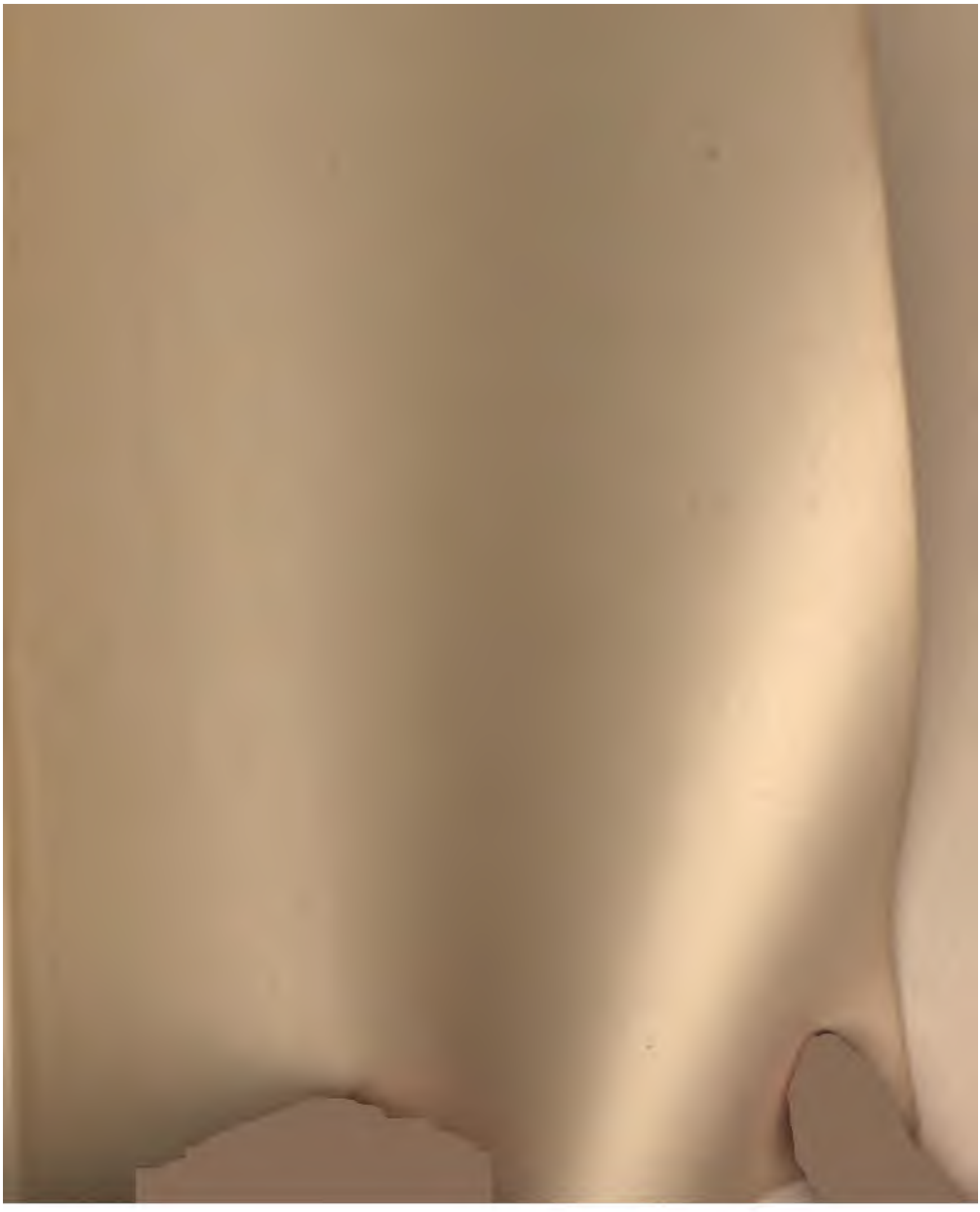

THE PRACTICAL APPLICATION

OF THE

RÖNTGEN RAYS

IN

THERAPEUTICS AND DIAGNOSIS

BY

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PART I.

X-RAY APPARATUS AND ITS USE IN DIAGNOSIS.

BY

E. W. CALDWELL.

PREFACE TO PART I.

In the seven years that have elapsed since the discovery of the *x*-ray very little has been added to our knowledge of the pure science of the subject beyond what is set forth in Röntgen's classical papers.

The art of applying these rays in medicine and surgery has steadily advanced, and valuable improvements in methods and appliances have been made by many enthusiastic workers in every part of the civilized world.

In the pages that follow I have not attempted to describe all the valuable work that has been done with the *x*-ray in diagnosis, but to present in a brief but fairly comprehensive way the methods and the various forms of apparatus with which the best results have been achieved. I have given special attention to many of the details which make up a good practical technique, and have devoted considerable space to the discussion of *x*-ray apparatus and the methods of using it.

There is a tendency among medical men either to underestimate the value of the *x*-ray as an aid to diagnosis or to fail to appreciate its limitations. I have therefore tried to show in a conservative way just what may and what may not be accomplished with it in the present state of the art.

Among those who are actively engaged in *x*-ray work there is a great diversity of opinion as to what type of apparatus and what methods of procedure are best. These varying opinions result largely from the fact that excellent work has been done with almost every known type of apparatus. I have tried to discuss impartially the merits of the different appliances employed in *x*-ray work, and to show what types are best suited for the different kinds of work and the various conditions of current-supply. In doing this one must necessarily make statements which are more or less dogmatic, and in which the

"personal equation" is an important factor. I have not hesitated to express my convictions freely, although some of them are not in accord with commonly accepted views.

The indications which the *x*-ray gives of pathologic conditions of the thoracic region is a large subject by itself, and has been ably discussed by many writers who are familiar with its medical aspects. I have therefore felt unable to do more than refer to their work and to tell how the examinations are made.

The discussion of the elementary principles of electricity and the description of simple electrical apparatus—batteries, electromagnets, etc.—are for a similar reason omitted from these pages.

In preparing this work I have gathered ideas from most of the existing books on the subject, and have contributed such of my own original work as seems to have an established practical value.

I am indebted to Dr. J. Mackenzie Davidson, Dr. W. Y. Cowl, Dr. Grunmach, Dr. E. W. Shenton, Dr. F. H. Williams, Dr. A. B. Johnson, and others eminent in *x*-ray work for courtesies extended to me in connection with their various developments of the art. To the founders of the Edward N. Gibbs *X*-ray Laboratory I am indebted for rare opportunities for observation and experiment in this fascinating field.

E. W. CALDWELL.

New York, April, 1903.

INTRODUCTION.

PROBABLY the first *x*-rays were produced by Crookes in his experiments on electrical discharges through vacuum tubes in 1875. He did not recognize the *x*-ray, and for twenty years following these experiments it remained unnoticed, and almost unsuspected.

In 1893 and 1894 both Herbert C. Jackson, of King's College, London, and Professor Lenard came very near making the great discovery. It remained, however, for Professor Wm. C. Röntgen, of Würzburg, to bring these rays from their hiding-place and give us some clue to their nature.

The study of the history of electrical discharges in rarefied air and gases leads us far back toward the beginning of the nineteenth century, but it was not until 1858-1859 that Geissler made the first vacuum tubes. These tubes were of comparatively low vacuum (about 0.0025 mm.), and the electrical discharge through them produced a delicate glow, sometimes striated, and varying much in form and color with the degree of exhaustion and the composition of the rarefied gases they contained.

Professor Hittorf about 1860 discovered that the luminous stream of discharge in a Geissler tube could be deflected by a magnet—a fact which has an important bearing upon the subsequent experiments of Crookes, Hertz, Lenard, and Röntgen.

The work of Geissler and Hittorf was followed several years later by the experiments of Crookes with discharge tubes of much higher vacuum (about 0.000001 mm.). With these high vacuum tubes Crookes discovered new phenomena. He found that with sufficiently high vacuum the luminous glow within the tube disappeared, and demonstrated that within

it there was a rectilinear radiation from the cathode which was a projection of particles of highly attenuated gas at exceedingly high velocity. He called this radiation cathode rays, and on account of the peculiar behavior of gas in this exceedingly rarefied state he conceived it to be as different from gas in its properties as ordinary air or gas differs from a liquid. He spoke of this highly attenuated condition as the fourth or radiant state of matter. He found that cathode rays were intercepted by metallic plates within the vacuum tube, that their impact against the glass wall of the tube produced in it a greenish phosphorescence and fluorescence and an increase in temperature. He concentrated these rays at the focus of a concave cathode, and by this means was able to produce brilliant fluorescence and a very high temperature both at the walls of the tube and in various substances within it. He also noted that the cathode rays were deflected by a magnet.

In 1892 Hertz announced that the cathode rays would penetrate gold leaf and other thin sheets of metal, within the tube. Soon afterward Hertz died, and his experiments were continued by his assistant, Lenard, who found that many of the phenomena of the cathode rays could be observed outside of the Crookes tube. He experimented with a vacuum tube closed at the end opposite the cathode with a thin sheet of aluminum, and found that the radiation which proceeded through or from the aluminum wall of the tube would pass through many substances opaque to ordinary light; after passing through such substances it would excite fluorescence in crystals of barium platino-cyanid and many other salts, and that it would affect sensitive photographic plates in much the same manner as ordinary light.

Lenard thought that all of these phenomena were due to the cathode rays alone, and, although it can scarcely be doubted that not only in his experiments but in those of Crookes, Hertz, and other investigators, *x*-rays were produced, they were not recognized, and it remained for another discoverer to bring the results of these long years of patient scientific research into practical application in our daily life.

Early in November, 1895, Professor William Conrad Röntt-

gen, then Professor of Physics at the Royal University of Würzburg, noticed that a piece of paper coated with barium platinocyanid fluoresced brilliantly in the neighborhood of a Crookes tube, even when the tube was covered with cardboard which intercepted all of the ordinary light. Further investigation proved that the fluorescence was caused by a radiation which emanated from the point of impact of the cathode ray against the glass wall of the vacuum tube. It was evident that this radiation did not produce the sensation of light, and that it passed readily through cardboard, which was opaque to ordinary light. Röntgen also noticed that all substances were transparent to this radiation, although in widely different degrees, varying roughly with the density of the material; that the radiation was rectilinear; that it could not be refracted or reflected to any appreciable extent, and that it was not deflected by a magnet. Hence it was obvious to him that this radiation was different from the cathode rays of Crookes, Hertz, and Lenard. He continued his observation both with the fluorescent screen and the photographic plate. Most of his early work was of a purely scientific nature, and had for its object to determine, if possible, the exact nature of the new radiation, which he named *x*-rays, probably because of the significance of the letter *x* in the mathematical formulæ.

Using photographic plates wrapped in black paper to protect them from ordinary light, Röntgen obtained with the *x*-ray shadow pictures of metallic objects in a wooden box and of the bones of the hand. The great possibilities of the *x*-ray in surgery were noted by him, and in December, 1895, he communicated his discovery to the Physico-Medical Society of Würzburg. This communication was published immediately all over the civilized world, and hundreds of investigators repeated the experiments of Röntgen and took up at once the work of practical development of his discovery.

The use of the *x*-ray in the diagnosis of fractures, location of foreign bodies, etc., at once became general, and in the first few months following its discovery experiments were made to determine its effect upon pathogenic micro-organisms in culture tubes. These experiments gave negative results, but

a little later a number of investigators observed valuable therapeutic effects when the rays were directed upon living tissues affected with tubercular or malignant disease.

The generally accepted theory of the *x*-ray is that it is a disturbance of the ether, somewhat of the nature of ordinary light, but differing from it in being a series of isolated impulses instead of a regular wave phenomenon. Although we do not know just what the *x*-ray is, the same thing may be said of gravitation and many other physical phenomena more familiar to us. For the purpose of the physician and surgeon it is quite sufficient to know how to produce and control the rays, but it may be well to remember that they originate within a Crookes tube at the point of impact of the cathode stream against a solid body; that they travel in straight lines; that they cannot be refracted or reflected as ordinary light; that, therefore, we can only obtain shadow pictures from them; that their range in quality is much longer than the range of the whole visible spectrum, and that the successful use of them depends upon the skill in those manipulations which secure for us the quality and intensity of the ray needed to accomplish the desired results.

Röntgen's first experiments were made with the familiar pear-shaped tube in which the source of the *x*-ray is spread over a comparatively large surface. Probably the most useful single contribution that has been made to the practical side of the subject is the suggestion of Mr. Herbert Jackson of using the focus tube of Crookes, thus reducing the source of the *x*-rays to a comparatively small area, enabling the production of sharp shadows, and making it possible to use a much stronger exciting current.

CHAPTER I.

THE ESSENTIALS OF AN X-RAY EQUIPMENT.

THE two essentials of an *x*-ray equipment are Crookes tubes, and apparatus capable of delivering electrical energy at sufficiently high potential to produce discharges through them.

In addition to the Crookes tubes and exciting apparatus an *x*-ray outfit comprises a vast number of auxiliary devices, such as tube-holders, switchboards, controlling mechanism for coils and static machines, plate-holders, fluoroscopes, operating tables, localizers, etc., which will be described in detail elsewhere.

The modifications of the Crookes tube which are used in practical *x*-ray work are made in many forms and fitted with many auxiliary devices. They consist essentially of sealed glass bulbs, containing two or three electrodes, and exhausted to a very high vacuum. One of the electrodes is made of aluminum, shaped like a concave mirror, and called the cathode because it is connected with the negative terminal of the exciting apparatus. Near the focus of this negative reflector is an electrode, which is usually a flat disc of platinum, connected with a terminal wire extending through the glass bulb. This electrode is commonly connected with the positive wire from the exciting apparatus, and is sometimes called the anode. However, the essential point about it is that it receives the impact of the cathode stream, and becomes the source of the *x*-rays. It has, therefore, been called the target or anti-cathode, and it may or may not be the anode of the tube. The various forms of tubes and methods of connecting them and regulating their vacua are described in detail in the next chapter.

For exciting Crookes tubes an electrical discharge of rather high potential is necessary. The potential required will vary with the resistance of the tube, but will always be much higher

than can be obtained directly from batteries or electric lighting circuits, and will in practical work be more than 100,000 volts. By comparison it may be said that the E. M. F. of an ordinary storage cell is about 2 volts, the incandescent lighting circuits are usually about 110 or 120 volts, the current used for operating trolley cars is about 500 volts, and in long distance power transmission alternating currents at 25,000 to 60,000 volts have been used.

Electrical discharges suitable for operating Crookes tubes may be obtained with a static machine, high-frequency coil, or from the ordinary induction coil. Excellent results have been obtained with all these appliances, and each has its peculiar advantages.

Influence Machines.—The influence machine, or static machine as it is commonly called, is an apparatus which converts mechanical energy directly into electricity at suitable potential for use with *x*-ray tubes. It consists essentially of a number of discs of glass or mica arranged to revolve in an enclosed case. An electrical charge is produced upon the surface of the revolving plates, collected from them by toothed collecting combs, and led out through the side of the case to suitable terminals. These machines are described more in detail in Chapter IV.

Induction Coils.—The induction coil is an electro-magnetic apparatus which transforms the energy of the ordinary electrical current derived from a battery, or electric lighting circuit, into discharges of suitable potential for exciting the Crookes tube. It consists essentially of a core of magnetic material, a primary winding consisting of a few turns of coarse copper wire through which the primary or exciting current flows, and a secondary winding of a great many turns of very fine wire in which a high potential secondary discharge is generated. The core is made of a bundle of fine soft iron wires, or strips of sheet-iron laid up in the form of a cylinder from 1½ to 3 inches in diameter, and from 1½ to 7 feet long. Upon this core the primary winding is wound in from 1 to 4 layers. Sometimes the ends of the different layers are brought out to separate terminals so that they may be connected together in various combinations. Outside of the primary winding and very carefully

insulated from it, usually by a thick hard-rubber tube, is the secondary winding of very fine wire about the size of a small sewing thread. The difference of potential in the different parts of this secondary winding is very great, and it is therefore necessary that great precaution be taken to secure thorough insulation of the various parts during its manufacture. In practice the secondary winding is usually imbedded in a mass of insulating wax. The ends of this secondary winding are provided with well-insulated terminals from which lead wires are carried to the Crookes tube.

The action of an induction coil is briefly as follows: An electrical current from a battery, or other sources, is passed through the primary winding, causing the core to become magnetic. Thus, a certain amount of the energy of the exciting current is stored up in the core. When the primary current is interrupted, the core very suddenly loses its magnetism and the energy stored up in it reappears as an electrical discharge of very short duration and very high potential in the secondary winding. In practical *x*-ray work this magnetization and demagnetization of the core are made to take place very rapidly—from 5 to 200 times a second. This is accomplished by various devices for rapidly starting and stopping the current through the primary winding of the coil. Such devices are known as interrupters. They have been made in many forms; some of the best-known types are described in Chapter III.

The degree of magnetization of the core increases at a comparatively slow rate, but its demagnetization is very sudden at the break of the primary circuit. The secondary discharge produced therefore at the opening of the primary circuit is of exceedingly short duration, probably not more than one-five-hundredth part of a second. In a coil operating at 50 interruptions a second there would be in one second 50 secondary discharges of exceedingly short duration followed by intervals of rest about ten or twenty times as long as the periods of the discharge. Thus it will be seen that there is a difference between the discharge obtained from an induction coil and that from a static machine, which when connected directly to the Crookes tube yields practically an even steady flow of current, much

weaker but occupying the whole period. However, Crookes tubes excited either with a static machine or coil produce practically the same effects upon the photographic plate, upon the tissues of the body, and, so far as the eye is concerned, upon the fluorescent screen.

High-frequency Coils.—The high-frequency coils of Tesla, Kinraide, and others operate in a somewhat similar manner to the ordinary induction coil, but they are excited not by an ordinary electric current interrupted suddenly a few times a second, but by a series of very rapidly oscillating currents of perhaps several hundred thousand alternations a second. Owing to the exceeding rapidity of the oscillations of the primary current, these high-frequency coils can be made to give high-potential discharges with a comparatively small number of turns of fine wire in the secondary winding. They produce brilliant *x*-ray effects, but they give discharges which alternate in direction, and which are, therefore, not so well adapted for practical *x*-ray work as those obtained from a static machine or ordinary induction coil. The alternations of the discharge cause much wear on the Crookes tubes, and they produce sources of *x*-rays at other points than the target, thus impairing the definition of the tube. For radiographic purposes, therefore, the high-frequency outfits are not very satisfactory, though for therapeutic work they answer very well, except for the rapid destruction of the tubes.

Available Sources of Electrical Energy.—The electrical energy necessary for operating *x*-ray apparatus may be obtained either from batteries or electric lighting or power circuits.

Batteries.—All forms of batteries are objectionable, because of the corrosive solutions they contain, because they deteriorate more or less rapidly, and because of the annoyance and trouble due to the corrosion of contacts, breakage, etc.

An electrical battery consists essentially of two electrodes of dissimilar materials immersed in a conducting solution of such a nature that chemical changes take place when the two electrodes are so connected that an electrical current may flow from one to the other. The energy of the current produced is derived from these chemical changes. In nearly all

primary batteries one of the electrodes is composed of zinc, and during the action of the battery this zinc electrode, or element, enters into chemical combination with the solution, and is worn away in proportion to the amount of current passed through it. It is therefore necessary after a time to renew both the zinc and the solution. On account of this troublesome and expensive process primary batteries are not recommended when other sources of electrical current are available.

There are several forms of primary batteries on the market which will deliver strong enough currents for operating induction coils. Of these may be mentioned the bichromate cell, having a voltage of 1.8, the Edison-Lalande with a voltage of 0.7, and the Gordon-Burnham with a voltage of about 1.5 a cell.

Storage Batteries.—In the storage battery the two dissimilar electrodes consist of two dissimilar oxids of lead which are held upon plates of metallic lead which serve as conducting supports for them. These are immersed in a solution of dilute sulphuric acid. In a storage battery the chemical changes which go on during the passage of the current are such that the original condition of the electrodes or elements may be restored by forcing a current through the cell in an opposite direction. It is therefore a much simpler matter to recharge a storage battery than a primary battery, because the elements do not have to be disturbed or renewed.

Lead storage batteries have an E. M. F. of about 2 volts and, since from 6 to 20 volts are required to operate an induction coil, from 3 to 10 storage cells will be needed. Some arrangement must be provided for charging these cells. They may be transported to a charging station, or if they are to be used for only a few minutes at a time at intervals of two to three days they may be charged by a primary battery, which does not deliver its energy fast enough for operating a coil directly, but which will store up in a day or two in a storage battery sufficient energy for operating a coil for a few minutes. The most suitable form of battery for this purpose is the ordinary gravity cell, which has been used extensively for telegraph work. These gravity cells will remain

in operation for several months on one charge, and may be connected permanently with the storage battery. About 3 or 4 cells of the gravity battery will be required for each storage cell. When a storage battery is allowed to remain discharged for some time, abnormal chemical processes go on, which seriously impair its usefulness. They should, therefore, not be allowed to become fully discharged, and should be kept as nearly as possible fully charged all the time.

Electric Lighting and Power Circuits.—These circuits may be divided into two classes—direct current and alternating current. The direct current lighting circuits furnish steady undirectional currents at a voltage of about 110 or 120 volts. Most of the railway and some power circuits furnish direct current at 500 volts.

The alternating current reverses its direction usually about 60 times a second, and it is distributed for electric lighting at about the same voltage as the direct current. It constantly changes its direction, producing entirely new phenomena and necessitating modifications for employing it in operating *x*-ray coils. For operating induction coils the direct current circuit of 110 or 120 volts is the best source of supply that may be obtained.

If the static machine is used, it may be operated by a motor driven from any one of these circuits, and it therefore makes very little difference what kind of a circuit is available, except that motors for the alternating current do not permit of speed regulation, but run at a constant speed, while direct current motors may be provided with means for speed control.

Several means have been devised for operating coils from an alternating current circuit. One method is to employ a motor generator which receives its power from the alternating current circuit, and delivers a direct current at from 50 to 100 volts.

To operate a coil directly from the alternating current circuit a cheaper, although not quite so satisfactory, method is to employ some special auxiliary device which allows the current to flow only in one direction, or which interrupts it only when

the current is flowing in one direction. For this purpose a Wehnelt interrupter may be used.

Fluorescent Screens and Photographic Plates.—The *x*-ray produces no sensation of light upon the eyes, therefore in order to employ it in diagnosis we must use intermediate means for making its effects visible. We have seen that photographic plates are affected by the *x*-rays in much the same way as by ordinary light, and that certain crystals are caused by it to fluoresce or give off visible light. We may interpose the object which we wish to examine between the photographic plate and the source of *x*-ray, and upon development of the plate a shadow-picture of the object will appear. In a similar manner we may obtain shadow-pictures on a piece of cardboard coated with a fluorescent material.

Photographic plates are caused to fluoresce by the *x*-ray, but it has not yet been determined whether the photochemical action is a secondary one due to this fluorescence, or is produced directly by the *x*-ray. In most fluorescent substances there is also a phosphorescence which persists after the *x*-ray has ceased. The substance which fluoresces most strongly and is best adapted for practical use, is the double cyanid of barium and platinum. This gives a bright greenish fluorescence with comparatively little phosphorescence. Tungstate of calcium, which was first brought into prominence by Edison, fluoresces and phosphoresces with a bluish light, which, although it does not affect the retina so strongly as the green light from the barium salt, has a much more powerful effect upon the photographic film or plate.

CHAPTER II.

X-RAY TUBES.

It is sometimes supposed that a Crookes tube is a standard article of manufacture, and that like an incandescent lamp it will have a definite number of hours of life; that it is adapted for a certain spark-length as a lamp is adapted for a certain voltage, and that in order to operate it all that is necessary is to turn on the current. A very little experience will suffice to prove the fallacy of such a supposition.

It is true that many tubes are rated for a certain spark length. These ratings are very indefinite, and may refer to the degree of exhaustion or to the size of the bulb. The degree of exhaustion is a constantly variable factor, and the size of the bulb is always an unimportant one. Consequently, these ratings are of little use, except that to a certain extent they may indicate the amount of material in the electrodes and therefore give an idea of the strength of the exciting current that may be used with them. A tube marked 15 cm. may be operated perfectly with a coil capable of giving a spark 100 cm. long, but, of course, such a tube will not withstand the heaviest discharges that may be produced with such a coil. A tube marked 60 cm. may be operated very satisfactorily with a coil of 20 cm. maximum spark length, but a 20-cm. coil will probably not furnish enough energy to produce the maximum excitation which the tube will withstand. Tubes marked 40 to 60 cm. are usually strongly made, and have heavy electrodes such as are suitable for use with exciting apparatus giving heavy discharges. The tubes marked 15 to 30 cm. usually have small bulbs and lighter electrodes, which will not withstand the heavy discharges of a large induction coil, but will operate very satisfactorily with a static machine or a small coil. The size of the bulb has little to do with the operation of a tube, but it will be obvious that the vacuum

of a large tube will not be so susceptible to change from the small amount of occluded gas as a tube of smaller size.

General Properties of Tubes.—The rays produced by different tubes vary widely in many respects. Some tubes produce rays of exceedingly high penetration, and rays from other tubes may have so little penetration that the shadow of the flesh of the hand is perfectly black, and the bones cannot be seen. Some tubes will produce sharp shadows on the fluorescent screen, and others give blurred images of any object held a short distance away from the screen. Some tubes operate steadily with very little change in the quality of the rays, while others will fluctuate rapidly from time to time during use. There are so many factors which vary the properties of a Crookes tube that it is almost impossible to make two exactly alike. Two tubes which are very nearly alike when new may after a few minutes' use be entirely different in character.

Definition.—For diagnostic work it is important to employ tubes which will produce sharp, distinct shadows of the object under examination. This condition will be obtained only in a tube in which the source of *x*-rays is at a comparatively small point on the surface of the target. The smaller this focus point of the cathode stream, the sharper will be the shadows. It must be remembered, however, that if this focus is exceedingly small, the intensity of the heat produced at the point will be correspondingly increased, therefore in a tube of exceedingly fine focus there is liability of melting a hole through the target at the focus point.

If the focus point is large, the shadows will have penumbra and all the fine detail will be lost. Such a tube, however, may be used safely with very strong currents, because the impact of the cathode stream is spread over a larger surface and is not so intense at any one point. For therapeutic purposes the matter of focus is unimportant. It is therefore well to use for this work tubes whose definition is not sufficiently good for diagnostic work.

For use in radiography and fluoroscopy tubes having focus points of not less than $\frac{1}{16}$ or more than $\frac{1}{8}$ of an inch in diameter will usually fulfil the requirements for definition and life.

Good definition in a tube is secured by having the cathode accurately ground, of proper curvature, and the target placed at the proper distance from the cathode. Owing to the mutual repulsion of the particles of the cathode stream they do not come to a focus at the distance of the radius of curvature of the cathode, but at a point beyond it, the distance depending somewhat upon the degree of exhaustion. In practice the distance between the target and the cathode is made not less than twice the radius of curvature, and in a well-designed tube the change in the position of the focus with the different degrees of exhaustion is so little that the definition is not seriously affected throughout the whole useful working range of vacuum. In every *x*-ray tube there is a certain amount of bombardment at other points than the target, and this gives rise to weak rays which are termed by the French operators parasitic rays. In certain tubes these may be strong enough to seriously interfere with the definition, but in a good tube these parasitic rays will be so much weaker than the rays originating at the target that they need not be considered.

Penetration.—The penetration of the rays derived from a tube depends upon a number of factors, but bears a close relation to the resistance which the tube offers to the exciting current. The resistance of the tube depends mainly upon its vacuum, but also upon the size of the electrodes, the distance separating them, and upon the amount of occluded gas in the electrodes. The character of the discharge used for exciting a Crookes tube may have much to do with the resistance which it offers and with the penetration of the rays obtained from it. For example, the discharge of a static machine may be so altered by a series of spark gaps in circuit with the tube that the discharge passes with difficulty through a tube of such low vacuum that without the spark gaps it would not possess sufficient resistance to cause the production of *x*-rays.

It is, of course, important to be able to control the penetration of the rays, and to regulate it to suit the different conditions of work. In order to accomplish this we must be able to regulate the resistance which the tube offers to the passage

of the exciting current.* The usual method of accomplishing this is by varying the degree of the vacuum, and a number of devices have been designed for this purpose.

As has been mentioned before, the degree of the vacuum of the tube is unstable and changes with use; the tendency of most tubes is to become higher in vacuum after continued use, until finally they become so high that re-exhaustion is necessary. A certain amount of gas is occluded on the inner surface of the bulb and especially upon the platinum target. When the tube is used, its temperature rises somewhat, and some of this occluded gas is driven off, thus temporarily lowering the vacuum, which rises again when the tube is cooled. In some tubes, however, there may be an exceedingly small leak through which air enters and very gradually reduces the vacuum.

From these facts it will be deduced that a satisfactory and convenient means for controlling the vacuum of an *x*-ray tube is very desirable.

Devices for regulating the vacuum were among the first developments of Crookes tubes for *x*-ray work, and in the following pages are shown a number of tubes with ingenious regulating apparatus of various types. However, no regulating device has yet been produced which gives as good control of the vacuum as may be desired, and many operators prefer to use plain tubes without auxiliary vacuum regulators.

Production and Dissipation of Heat in Tubes.—The impact of the cathode stream upon the focus point of the target produces heat as well as *x*-rays, and with the powerful exciting apparatus which is necessary for rapid radiographic work the amount of heat evolved will be great enough to melt a hole through the ordinary platinum target. For this work it is therefore necessary to employ tubes with targets which are capable of withstanding a great rise of temperature, or of dissipating a considerable amount of heat. One method of accomplishing this is to make the target of a considerable

* The word resistance as applied to *x*-ray tubes is not a very good one. Obviously the passage of an electrical discharge through a Crookes tube is essentially different from the flow of an electric current through a metallic conductor, and the obstruction which the tube offers to the discharge differs from the electrical resistance of a metallic conductor.

mass of metal having large thermal capacity. Some makers have employed large targets of copper or some alloy, sometimes faced with a thin sheet of platinum, and occasionally blackened to facilitate radiation of heat from them. The difficulties of these cheap metals are that they cannot be heated to a very high temperature without giving off so much vapor that the vacuum of the tube is reduced to such a point as to render it useless for the time being. With very short exposures, however, the large thermal capacity of the mass of metal, and its high conductivity for heat prevent a great rise of temperature, and they work very well. Platinum does not vaporize in the tube, and a target having a large mass of this metal may therefore be heated to a very high temperature without seriously impairing the vacuum. The high price of platinum makes such tubes very expensive, but when it is considered that the platinum is not destroyed, and that the same target may be used for making a new tube, this matter is not so important. The author has tubes with targets containing from $25.00 to $50.00 worth of platinum which have been re-made several times at comparatively small expense. Iridium and osmium are harder and will withstand higher temperatures than platinum, but these metals are rarer and more expensive than platinum. However, a heavy platinum target faced with a small piece of iridium at the focus point of the cathode stream makes a very satisfactory arrangement, and its expense is not prohibitive. These metals, however, give off gases in an exceedingly irregular manner, and it is therefore necessary with such tubes to use a regulating device of wide range and great efficiency.

Cooling the target by a stream of water or oil in contact with it has been attempted by a number of makers. One of the first of these tubes was that devised by Dr. Rollins in which the target consisted of a long platinum tube sealed in the bulb, and provided with an inlet and outlet through which the cooling liquid could be circulated. These tubes were very expensive on account of the large amount of platinum necessary.

Some makers have placed in contact with the target a glass chamber through which the cooling liquid is circulated. This

construction obviates the difficulties of sealing the large platinum tube in the glass, but in these tubes the heat must be conducted through the glass before it can be absorbed by the liquid. Glass is such a poor conductor of heat that in practice the target of such a tube may be dangerously heated before the liquid within the cooling chamber shows an appreciable rise in temperature.

Müller, of Hamburg, has succeeded in making a tube in which the target consists of a cap of platinum sealed in the end of a glass tube which projects within the bulb, and which outside of the bulb is enlarged into a little bottle for containing the cooling liquid. This construction, like that of Rollins, permits the liquid to come in direct contact with the metal of the target. Of the water-cooled tubes this is unquestionably the most effective. The high specific heat and the large mass of the liquid prevent it from attaining a high temperature during any ordinary radiographic exposure, but even in such a tube with the water in direct contact with one side of the thin platinum target the discharge from a powerful induction coil may cause the face of it to become white hot.

For use with static machines and induction coils of small size, such as are used for ordinary fluoroscopic work and for therapeutic purposes, such elaborate cooling devices are quite unnecessary. For the most rapid exposures in radiographic work it is necessary to use very powerful discharges, and no tube has yet been produced which will withstand as much current as it is desired to use. The most effective tubes for this work are the water-cooled tubes and those with heavy targets.

Operation of the Tube.—Success in radiographic work, or, in fact, in any kind of *x*-ray work, depends largely upon the proper manipulation of the tube. This is the most difficult part of the subject to acquire, and proficiency in it can be obtained only by experience, and probably at the cost of a good many ruined tubes.

X-ray tubes are exceedingly fragile, and easily damaged. It is therefore necessary to observe certain precautions in using them in order to prevent puncture, or breakage, or blackening the bulb and seriously impairing the vacuum.

Temperature.—Tubes should not be used when they are very much cooler than the temperature of the room, as will be the case when an expressman has delivered one on a winter's day. It is a good plan to warm the tube gently over a radiator until the temperature reaches 60° to 70° F.

Clamping the Tube.—The various holders for supporting the tube in operation are described in another chapter, but it is perhaps advisable to repeat cautions against clamping the tube so strongly as to put the glass upon a strain, and thus render it liable to crack or puncture, or, on the other hand, clamp it so loosely that a little pull upon the connecting wire will detach it, and let it fall and break. The clamping part of the tube-holder should be carefully examined to see that it fits the tube. It should be lined with some yielding substance such as cork or felt to prevent undue strain.

Most of the tubes are provided with a small projecting tip, sometimes covered with a piece of soft-rubber tubing, for the tube clamp, but these tips are usually too small to give a good firm grip on the tube, and with a proper clamp it is better to support the tube as near the bulb as possible. The most convenient point is around the neck which carries either the cathode or anode, but usually the cathode.

Connecting Wires.—The connecting wires should be as small and flexible as the requirements for mechanical strength will permit. A copper wire as large as a small sewing thread has ample carrying capacity for the strongest currents which will be used in exciting the tube. A thick, heavy wire is awkward to manage, and with it the platinum terminal wires of the tube are very liable to be broken off. For use with an induction coil a very convenient lead wire for the tube is the ordinary bare tinsel cord, to the end of which is attached a short piece of copper wire, about No. 24 B. & S., which may be bent into a hook for attachment to the terminal of the tube. With this tinsel cord it is very convenient to have two spools upon which it may be wound. These spools make it easy to adjust the length of the cords so that they do not lie across the bulb, where they would probably produce a puncture, or across the secondary of the coil, where a spark is liable to pass and

injure the insulation. The lead wires should be separated from each other at every point by a distance of not less than six or eight inches, and they should not be approached nearer than four inches to the body of the patients or to metallic objects, such as gas pipes or metal parts of the apparatus, for the reason that the spark might pass and give a shock to the patient, or, by grounding, unnecessarily strain the insulation of the coil.

With a static machine there is a tendency for brush discharges to form from any exposed points connected with the terminals. Bare tinsel cord cannot therefore be used, and it is necessary to heavily insulate the lead wires. In order to prevent these brush discharges, and at the same time secure maximum flexibility I have used a very small conductor made up of seven No. 33 copper wires passed through an ordinary soft rubber tube about one-fourth of an inch in diameter.

Before connecting the tube it is well to ascertain the polarity of the terminals of the exciting apparatus. The negative terminal of the exciting apparatus should be connected with the cathode,—which is the cup-shaped aluminum electrode,—and the positive terminal with the target or anode. It is advisable to have the exciting apparatus provided with an arrangement which enables a spark gap to be put in series with the lead wires, and which allows the length of this spark to be adjusted while the tube is in operation. The object of the gap is twofold—a certain amount of regulation of the quality of the rays may be obtained with it, and with the coil it prevents, to a certain extent, the inverse discharge, produced at the make of the primary current, from passing into the tube and blackening it or interfering with its operation.

It is always advisable to start the tube with a weak exciting current and increase the strength gradually until the desired effect is obtained. This is a precaution which will often prevent puncturing the tube.

If the tube is of moderate vacuum, such that the terminals of the exciting apparatus must be approached within three inches before a spark passes between them, in preference to passing through the tube, the bulb will light up with a yellowish-

green fluorescence, the shade depending largely upon the material of the glass and the length of time the tube has been used. This fluorescence will be confined almost entirely to the hemisphere on one side of the plane of the target, and its intensity will vary with the strength of the exciting current. In the hemisphere back of the target there will be a slight trace of fluorescence, and perhaps a trace of a delicate bluish glow within the bulb back of the anode. Such a tube is operating properly, and the strength of the exciting current may be gradually increased until the desired intensity of the rays is obtained, or until the target begins to show signs of undue heating. The appearance of a tube operating in this way is shown very well in figure 1.

If by mistake a tube has been connected with the wrong poles of the exciting apparatus, the appearance is quite different. There will be an irregular illumination at different parts of the bulb, and bright rings will probably appear on the glass. The appearance of a tube connected in this way is very well shown in figure 2. If a tube is connected in this way, the direction of the exciting current through the tube should be reversed. Running a tube in the reverse direction tends to blacken the bulb with a fine deposit of metal thrown off from the electrodes, and make it subject to very sudden and erratic fluctuations in resistance.

If the resistance of the tube is so low that the discharge rods of the exciting apparatus may be approached within an inch of each other before a spark passes, there will be a bluish glow within the bulb, and sometimes a cone-shaped glow may be detected extending between the faces of the cathode and target. The penetration of a tube operating in this manner is too low for practical *x*-ray work, and unless it is provided with means for increasing its resistance or for increasing its penetration by the spark gap methods, it will have to be sent to the makers for re-exhaustion. The appearance of a low vacuum tube is shown very well in figure 3.

It may be that when the exciting current is turned on, the resistance of the tube is so high that it does not light up steadily, but flashes faintly, and sparks have a tendency to pass around

Fig. 1.—X-ray Tube Operating Properly.

FIG. 2.—APPEARANCE OF X-RAY TUBE WITH CURRENT REVERSED.

on the outside of the glass. This is a signal to turn off the current quickly, for in this condition the tube is very likely to be punctured. It is well to have the discharge rods of the exciting apparatus separated not more than six or eight inches in order that the discharge may pass between them in preference to running around the wall of the tube where it is liable to do damage.

If the tube is provided with one of the regulating devices, its vacuum will be readily lowered. If a tube has no vacuum regulator it may be lowered by heating it gradually in the flame of an alcohol lamp. A certain amount of gas may be liberated in this way from any part of the walls of the tube. Unless it is very old, sufficient gas may be driven off so that the discharge will pass through the tube, and after it begins to operate, the heating of the target will usually drive off enough occluded gas so that the vacuum will not rise above the working point when the glass walls become cooler again. The most effective point for heating the bulb is in the neighborhood of the cathode, but this is the point where the greatest care must be exercised in order to avoid cracking the glass. If the vacuum of the tube is very high, it may be lowered permanently by baking it for an hour or two in an oven at a temperature of 300° to 400° F. The tube, of course, must not be allowed to come in contact with the metal parts of the oven, and care must be taken not to lower the vacuum beyond the working point.

With a static machine tubes that are high in vacuum will frequently start if a small spark gap be opened on the positive side of the machine. Running the tube reversed for a few seconds will sometimes lower the vacuum, but tubes behave so differently that no fixed rules can be given for managing them.

Punctures.—I have already alluded to the fact that under certain conditions a spark may pass through the glass bulb and puncture it. When this occurs, there is usually a minute hole or crack, which is scarcely discernible, but which is sufficient to allow air to enter and destroy the vacuum of the tube in a very few minutes. If the tube is kept running after it

is punctured, a series of beautiful effects will be observed, and the appearance of the discharges through varying degrees of vacuum may be noticed until finally the bulb is full of air and sparks pass between the electrodes. The appearance of the punctured tube at one stage is shown in figure 4. When a tube is punctured, it should be sent to the maker, who can seal up the hole and re-exhaust the tube to proper vacuum.

Testing the Tube.—After the tube has been in operation, the first step is to determine whether the penetration, definition, and intensity of the rays are suitable for the work to be done.

There is, so far, no satisfactory standard for measuring or rating the vacuum of the tubes or the penetration of the rays obtained from them. Tubes are commonly called hard, medium, or soft, according to whether the penetration is high, medium, or low. These terms do not mean exactly the same thing with any two observers. The three examples of high, medium, and low vacuum tubes mentioned above represent fairly well these three stages.

A more satisfactory method of rating the penetration of a tube is to express its resistance in terms of the distance through which a spark gap will pass between the lead wires in preference to passing through the tube.

With a tube of such low vacuum that the discharge rods may be approached within 1¼ inches of each other before the spark passes, the hand will cast a dark shadow on a brilliantly illuminated screen, and the shadow of the fleshy parts will be dense enough to obscure to a certain extent the shadows of the bones.

With a medium tube the range of the alternate spark gap will probably be from 1½ to 2½ inches, and the shadows of the bones will appear very distinct and clear, and will be slightly illuminated, because they do not obstruct all of the rays.

With a tube of higher vacuum the resistance may be equivalent to an alternate spark gap of 4 to 7 inches, and the penetration of the rays may be such that the shadows of the bones of the hand are of a grayish color, with very little contrast between the bones and flesh.

FIG. 3.—APPEARANCE OF X-RAY TUBE WHEN OPERATING AT VERY LOW VACUUM.

FIG. 4.—APPEARANCE OF DISCHARGE THROUGH X-RAY TUBE A SHORT TIME AFTER THE BULB HAS BEEN PUNCTURED OR CRACKED (BULB PARTIALLY FILLED WITH AIR).

Testing the tube by observing the shadows of the hand in this way is very convenient, but it is not to be recommended for the reason that the skin on the back of the hand is very sensitive to the *x*-rays, and burns are perhaps more liable in this area than any other part of the body. Indeed, most men who have had much experience in *x*-ray work have had more or less difficulty from this cause, and several have been badly burned, necessitating in some cases the amputation of the fingers or the hand. It is, therefore, better to judge the penetration of the tube from the length of the alternate spark gap, or by its general appearance. It must be borne in mind, however, that the length of the alternate spark gap for a given penetration will not be exactly the same in different tubes, and that it will vary somewhat with the strength of the exciting current, and will be longer when the current is stronger than when it is weak.

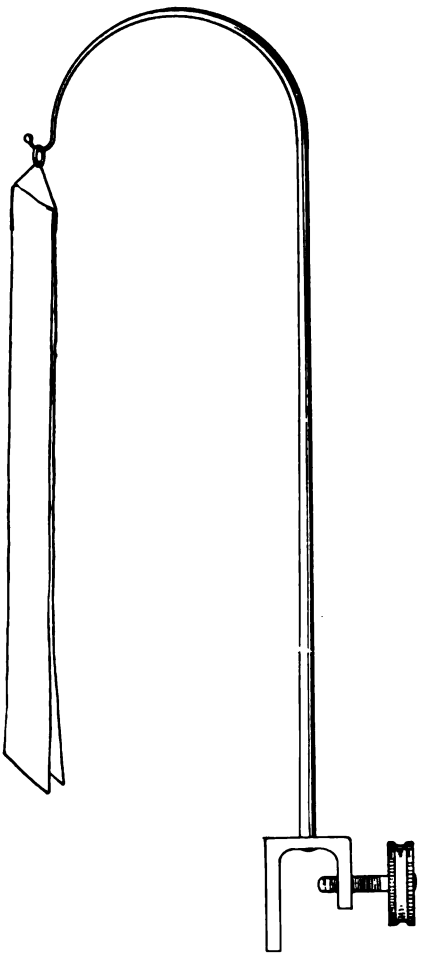


Fig. 5.—Tinfoil electroscope for indicating the potential at the terminal of a Crookes tube.

Another means of indicating the penetration of the tube is by the use of a modification of the gold-leaf electroscopes which I have made for this purpose, and which is shown in figure 5. In this electroscope the movable leaves are made

of two strips of tinfoil about ¾ of an inch wide and 5 inches long, arranged to be suspended in the air. This appliance is connected with one of the terminals of the exciting apparatus or one of the lead wires, and indicates the potential at the terminal of the tube by the amount of divergence of the leaves. When the vacuum of the tube is low, the potential of the lead wires is correspondingly low, and the leaves of the electroscope separate only a short distance; but with a high resistance tube the separation may be as much as 1½ inches or more. The use of the electroscope is open to the objection that the divergence of the leaves will vary to some extent with the strength of the exciting current as well as the potential of

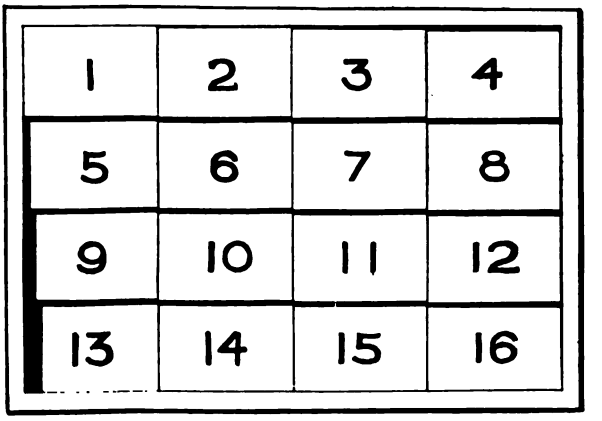


Fig. 6. — Device for measuring penetration of *x*-rays.

the lead wires. However, it is convenient because it gives a constant indication of the condition of the tube, and is free from the noise and sparks incident to testing from time to time with the alternate spark gaps.

The penetration may also be tested by observing the number of leaves of tinfoil which must be interposed between the tube and a small piece of fluorescent screen before the rays are entirely cut off. A number of measuring devices of this sort have been made, and one of the common forms is shown in figure 6. This consists of a card which may be attached in front of the screen of a fluoroscope and which is covered with

squares of tinfoil in a varying number of layers, and so arranged that one may observe at what point the rays fail to produce an effect upon the screen. Such methods are exceedingly inaccurate, because their readings will vary with the sensitiveness of the screen and with the sensitiveness of the eye. The eyes of different observers will, of course, be widely different, and the condition of the retina of one observer will be very different at different times, depending upon the amount of exposure to light immediately preceding the observation.

The platinum-aluminum window of Röntgen is the only means which has been suggested for accurately measuring and standardizing the penetrating quality of the *x*-rays. Apparently, this method is free from errors due to the differences in the sensitiveness of the eye, the efficiency of the screens, or the intensity of the ray.

Röntgen's original platinum-aluminum window is described in his third paper as follows: "A rectangular piece 4 by 6.5 cm. of platinum-foil of 0.0026 mm. thickness, which is cemented to a thin paper screen, and through which are punched 15 round holes, arranged in 3 rows, each hole having a diameter of 0.7 cm. These little windows are covered with panes of aluminum, 0.0299 mm. thick, which fit exactly, and are superimposed in such a way that at the first window there is 1 disc; at the second, 2, etc.; finally, at the fifteenth, 15 discs. If this arrangement be brought in front of the fluorescent screen, it may be observed very plainly, in case the tubes are not too hard, how many aluminum sheets have the same transparency as the platinum-foil. The number will be called the window number.

"For the window number I obtained in one case by direct radiation the value 5. A plate of common soda glass, 2 mm. thick, was then held in front—the window number was 10. So that the ratio of the thickness of the platinum and aluminum sheets of equal transparency was reduced one-half when I used rays which had passed through a plate of glass 2 mm. thick instead of using those coming direct from the discharging apparatus.

"The ratio of the thickness of two equally transparent plates

of different substances is also dependent upon the hardness of the tube used. This may be recognized immediately with the platinum-aluminum window; with a very soft tube, for example, the window number may be found to be 2; while with a tube which is very hard but otherwise the same, the scale which reaches 15 does not extend far enough. This means, then, that the ratio of the thickness of platinum and aluminum of equal transparency is smaller in proportion as the tubes from which the rays come are harder or—with reference to the results reported above—as the rays are less easily absorbed."*

It is to be hoped that the *x*-ray societies will take up this matter of standardizing the quality of the rays delivered by the *x*-ray tubes, and adopt a standard apparatus based on this principle. The use of it will enable one to accurately describe the quality of the ray which is employed. At present this is quite impossible.

Some idea of the definition of the tube may be obtained by observing the shadow of the hand in the fluoroscope. A tube with good definition will always give sharp, clear shadows. When it gives a blurred or indistinct image of the hand, it has not sufficiently good definition for either radiographic or fluoroscopic work. A better method of testing the definition of a tube is to hold the fluoroscope with the screen at about 18 inches from the target of the tube, and move back and forth between the screen and the tube a small metallic object such as a key or a piece of heavy wire gauze. It will be observed that when the object is in contact with the screen the shadows are very sharp, but as it is moved further and further away from the screen and closer to the tube the shadows become larger and at the same time the margins become less sharp and distinct.

A tube which has sufficiently good definition for making radiographs of the hip-joint or shoulder should show these outlines sharply when the key or wire gauze is held at a distance of 8 inches from the screen with the screen not more than 18 inches from the target of the tube. Good definition will

* From Röntgen's third paper.

usually be obtained from a tube which is well focused, and such a tube may be detected by observing the manner in which the target heats up when it is started. If the heating begins with an exceedingly small red-hot point on the target, this is an indication that the tube is accurately focused.

It is well to mark the tubes in some way after they have been tested, and to reserve those which are of bad definition for therapeutic purposes.

The Choice of an X-ray Tube.—The choice of *x*-ray tubes is a matter upon which operators have widely different opinions, and I therefore describe here a number of tubes representing the principal types employed by the most successful operators. Of the different varieties some are better adapted for one purpose and some for another, and it is therefore advisable to have two or three kinds of tubes in one's collection.

Fig. 7.—Jackson single focus tube.

In a good tube the glass should be smooth and free from uneven spots, the electrodes should be well made and strongly supported so that they do not rattle when the tube is shaken. The terminals for connecting the lead wires should be strong and so supported that they will not be liable to be bent or broken in use.

For *x*-ray treatment, for fluoroscopic examinations, and for radiographic work where the fastest exposures are not required, it is perhaps better to use the less complicated forms of tubes. The simplest and one of the best of these is the ordinary Jackson single focus tube which is shown in figure 7. These tubes are sold by nearly all the makers, and they differ much in effectiveness according to the care which has been taken in mechanical construction and in the exhaustion.

Bi-anode Tube.—Many of the tubes of German manufacture have in addition to the two electrodes of the tube shown above, a third which may be connected in various ways. This type (shown in figure 8) is probably used more than any other. The third electrode gives us some advantage in the regulation of the resistance. The highest resistance will be obtained by connecting the negative wire to the cathode A, and the positive

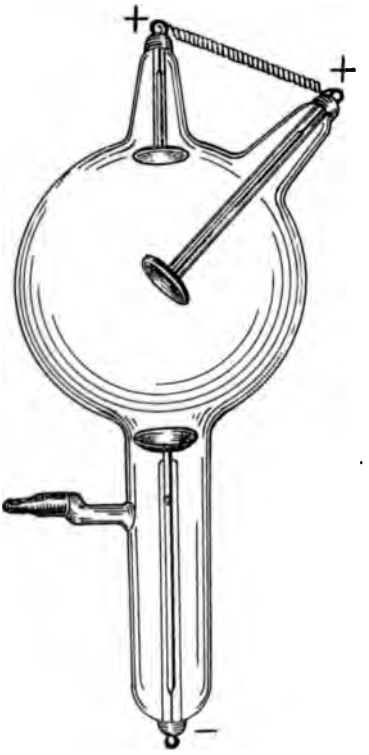


Fig. 8.—"Bi-anode" tube.

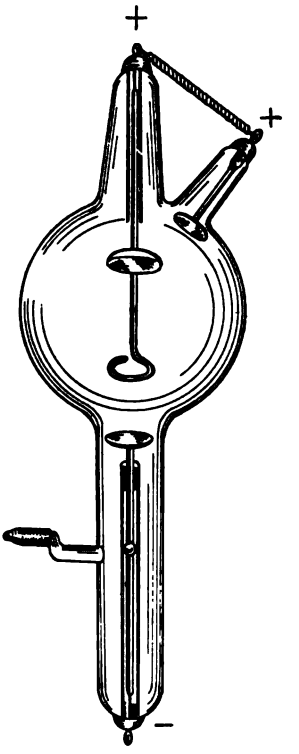


Fig. 9.—Penetrator tube.

wire to the target terminal B. When the positive wire is connected to the third electrode C alone, the current will pass much more readily, and the rays will be of lower penetration. Penetration intermediate between these two points can be obtained by connecting the terminals of the target and the electrode C together, both being connected with the positive wire.

Penetrator Tube.—This tube is made by Müller and others and is shown in figure 9. It is based upon the principle that with a given vacuum the penetration will be higher the closer the electrodes are together. In this tube a ring of metal is extended out from the target to a point between it and the cathode. Such tubes are preferred by some operators for fluoroscopic work in which a very high penetration is desired.

Tubes with Vacuum Regulators.—Devices for regulating and controlling the vacuum were among the first developments of Crookes tubes for *x*-ray work. One of the first methods employed was that which had been used by Crookes in his early experiments, and consists in providing a tube with an auxiliary chamber containing potassium or sodium hydrate. By applying heat to this auxiliary bulb a certain amount of

Fig. 10.—Thomson's vacuum regulator tube.

the water of crystallization of the salt is driven off and lowers the vacuum. When the bulb cools again, the vapor is reabsorbed. Thus a considerable range of regulation of the vacuum may be obtained.

Thomson Tube.—Elihu Thomson applied this method of regulation to tubes for *x*-ray work, and modified it by sealing a platinum electrode through the auxiliary bulb so that the vapor could be liberated by passing sparks through the salt. This tube is shown in figure 10. Regulation of this tube may be made automatic by carrying a wire from the terminal of the auxiliary chamber to a point a few inches from the negative wire of the exciting apparatus. When the vacuum of the tube rises to such a point that the discharge passes with difficulty between the anode and cathode, a spark will jump from the

negative wire to the wire connecting with the auxiliary chamber. After the discharge has passed through the auxiliary chamber for a little while the vacuum of the tube will be lowered, and the discharge will again pass through the main terminals of the tube. It is obvious that the degree of vacuum which will be maintained by this method will depend upon the distance through which the regulating spark must pass. If this distance is made very small, the discharge passes readily through the regulator and a low vacuum will be maintained; but if the regulating spark gap is long, the vacuum of the tube may have to become very high before the sparks will pass through the regulator to reduce it.

Bario-vacuum Tube and Regulator.—The bario-vacuum tube shown in figure 11 is operated on precisely the same principle

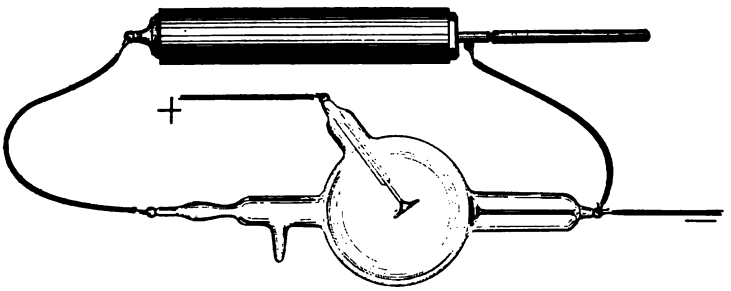


Fig. 11.—Bario-vacuum tube with regulator.

as the one just described, but the auxiliary regulating chamber is placed at the end of the bulb directly opposite the cathode. It is designed for automatic regulation by the method above described, and the regulating spark gap is enclosed in a hard-rubber tube for the purpose of lessening the noise and concealing the flashes of light. The sliding rod extending from the end of the regulator tube enables the length of spark gap to be adjusted for any degree of vacuum.

Sayen Tube.—In 1896 Mr. Sayen patented a tube with an automatic vacuum regulator, and which is sold as the Queen Self-regulating Tube. This tube is shown in figure 12, and described in Queen's catalogue as follows:

"A small bulb, X, containing a chemical which gives off vapor when heated and reabsorbs it when it cools, is directly connected to the main tube, B, and is surrounded by an auxiliary tube, D, which is exhausted to a low Crookes vacuum. In the auxiliary tube the cathode is opposite to the above-mentioned bulb, so that any discharge through it will heat the bulb by the bombardment of the cathode rays. This cathode is connected to an adjustable spark point, P, the end of which may be swung to any desired distance from the cathode, K, of the main tube. The anode of the small tube is directly connected to the anode, A, of the main tube. The coil is connected as usual to the main tube, which has been exhausted to a very high vacuum, and consequently has a high resistance equal to ten inches of air or more. When it is put in operation, the vacuum of the main tube being high, and consequently having high resistance, the current takes the path of least resistance by the spark point and the auxiliary tube, which, being a low Crookes vacuum, has a very small resistance, and heats the chemical in the small bulb, X, thereby releasing the vapor which it contains in state of absorption and driving it into the main tube, B. This will continue for a few seconds until a sufficient amount of vapor has been driven into the main tube to permit

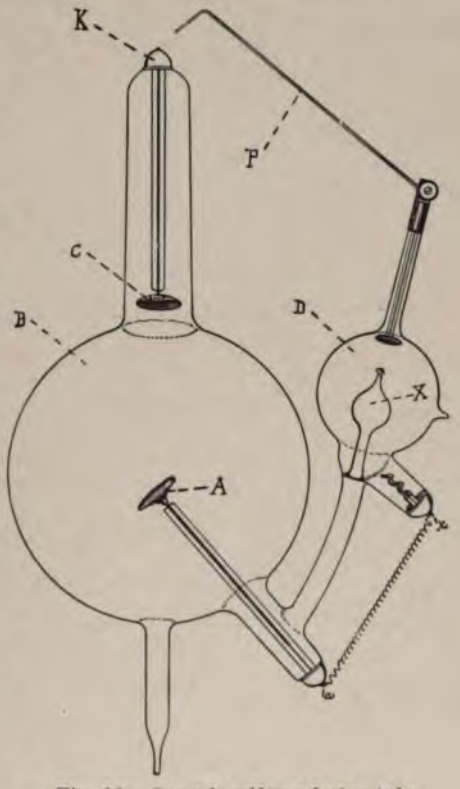


Fig. 12.—Sayen's self-regulating tube.

the current to go through it, which will begin to take place when the vacuum has been reduced until the resistance of the main tube is brought down to that of the spark gap plus the small resistance of the auxiliary bulb. After this only an occasional spark will jump across the gap to counteract the tendency of the chemical as its bulb cools to reabsorb vapor and raise the resistance of the main tube. The tube is thus maintained at a constant vacuum while running. When the current is stopped the chemical cools off and reabsorbs vapor and the tube returns to its starting condition of high vacuum.

"It will be evident from the above that the height of the vacuum at which the tube runs will depend on the resistance of the circuit through the auxiliary bulb—in other words, on the length of the spark gap. The tube may be set to run at high vacuum by placing the spark point at a considerable distance from the cathode terminal of the main tube, or to run low by placing it near. The adjustability of the vacuum is of the utmost importance, as the penetrating power, photographic effect, and ability to brilliantly light a fluorescing screen all depend upon the degree of exhaustion, and that degree of vacuum which is best for one operation is not best for another."

This regulator is very satisfactory when the tube is to be used for a considerable period of time—two to three minutes. It has the disadvantage that the conduction of heat through the glass walls of the auxiliary chamber requires an appreciable time, and before the sparks in the auxiliary chamber stop so much heat has been stored up in the glass of the auxiliary chamber that the vapor continues to come off after the regulating sparks have ceased. When the tube is first started, therefore, there is a tendency for the vacuum to become much lower than is desired. After a few minutes' running, however, the vacuum chamber attains fairly constant temperature, and only occasional sparks through the auxiliary chamber are necessary for further regulation. When this condition is reached (usually after one or two minutes), the tube is quite steady, and any degree of vacuum may be automatically maintained.

Müller's Regulating Tube.—A tube, similar in some respects to the Sayen tube, is manufactured by Müller, of Hamburg, and is shown in figure 13. This tube has an auxiliary chamber and an adjustable regulating spark gap, but it differs from the Sayen tube—having the regulating discharge pass directly

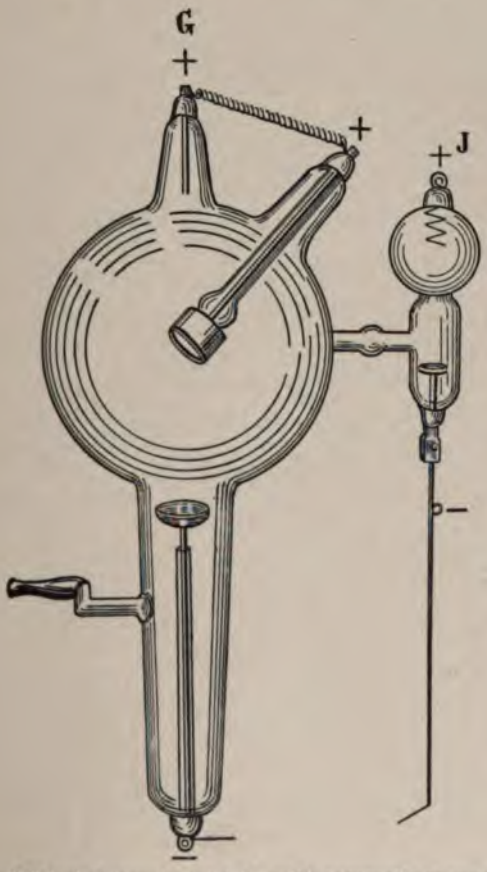


Fig. 13.—Müller's heavy target tube with automatic vacuum regulator.

into the auxiliary chamber instead of through a second vacuum chamber. In Müller's tube the regulating discharge passes through a bundle of mica discs, and lowers the vacuum of the tube by driving off occluded gas from them instead of liberating vapor of crystallization from a salt, as in Sayen's

tube. The action of this regulator is not delayed by the slow conduction of heat through the glass of the auxiliary chamber, and is therefore a little quicker. Another feature of the Müller regulator is the arrangement for raising the vacuum of the tube when it becomes too low. This is accomplished by disconnecting the wire from the anode, G, of the tube proper and connecting to the terminal, J, of the palladium electrode within the auxiliary chamber. The discharge which passes under these conditions causes more gas to be occluded on the palladium electrode. Thus the vacuum of the tube may be somewhat increased.

One disadvantage of all automatic regulators in which the lowering of the vacuum is effected by allowing the discharge to pass through a by-path is that while the regulating sparks

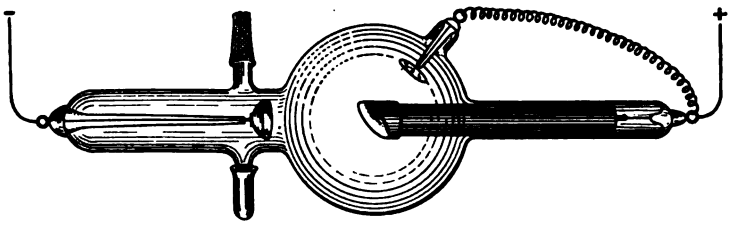


Fig. 14.—Gundelach's heavy target tube with osmosis regulator.

are passing there is no discharge through the tube proper. The target then cools a little, and occludes upon its surface some of the gas. The regulation continues until its proper vacuum is obtained with the target cooled, and as soon as the discharge passes again through the tube the target heats up and may drive off enough gas to make the vacuum too low. In other words, while the regulator is in operation the current is taken away from the tube proper, and the adjustment of the vacuum is made under conditions which are somewhat different from those when the whole discharge is passing through the tube.

Tubes with Osmosis Regulators.—Another method of regulating the vacuum depends upon the fact that certain metals, such as platinum, become porous when heated to a red heat.

A closed tube of platinum may be sealed into the bulb of an *x*-ray tube, and when cold, it will be perfectly tight. When the vacuum of the tube becomes too high, the little platinum tip may be heated to a red heat by a spirit lamp for a few minutes, and the temperature of the metal will rise and allow a little gas to enter through its pores into the bulb, and thus lower the vacuum. This type of regulator has been used by a number of makers. One of Gundelach's tubes with such a regulator is shown in figure 14. Another one is the "osmo-regulator" tube of Dean, shown in figure 15. It is said that

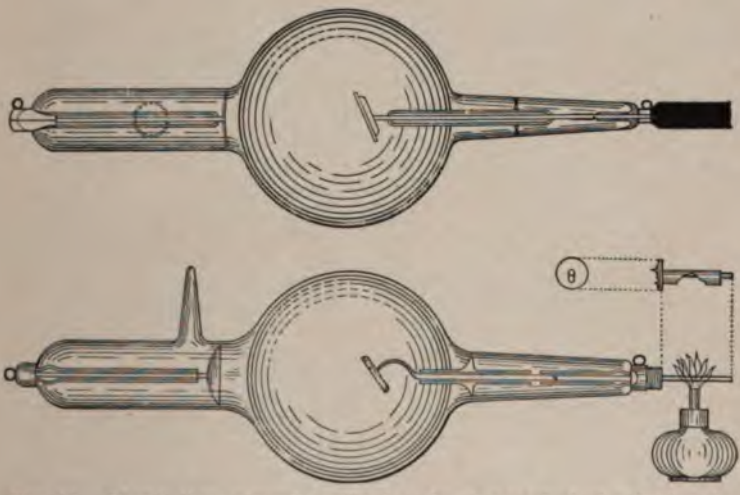


Fig. 15.—Dean's "osmo-regulator" tube, showing method of reducing the vacuum.

with this regulator the vacuum of the tube may be permanently lowered. It is very highly recommended by some operators who use it.

Hirschmann's Tube.—In this tube the vacuum may be lowered by turning the valve A, which admits a small amount of air into the bulb. The tube is also provided with an auxiliary chamber, B, which is coated on the inside with a substance which may be made to occlude a considerable amount of gas when the current is passed through the electrode C. The object of this device is to enable the vacuum to be raised. Lowering

the vacuum by the admission of air through the valve does not, of course, admit of very fine adjustment (see Fig. 16).

Water-cooled Tubes.—Water-cooled tubes have been produced by a number of makers, and a typical one is that of Müller, shown in figure 17. Water-cooled tubes with a bottle for containing the cooling liquid are preferable to those in which the liquid is circulated. The circulating pipes and reservoirs are clumsy, and if water is used, the difficulty of insulating them is to be considered.

Tubes with Heavy Targets.—A tube of Müller's which is designed for use with very strong exciting currents is shown in figure 13. It does not differ essentially from the other

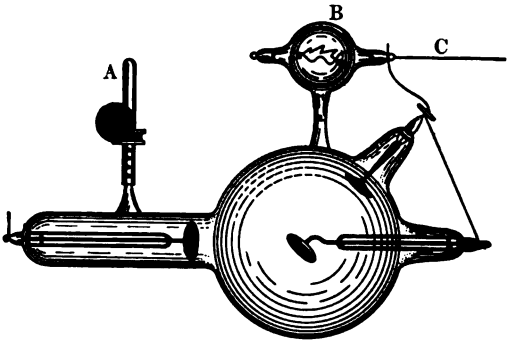


Fig. 16.—Hirschmann's tube with valve for admitting air to lower the vacuum.

bi-anode tubes, except that the target contains a large mass of metal having large thermal capacity and does not become quickly heated.

Gundelach's heavy target tube for use with electrolytic interrupters is shown in figure 14. In this tube the target is made of a heavy mass of metal usually faced with a thin sheet of platinum, and provided with a long tubular projection of metal which is designed to increase the radiating surface. This tubular projection is blackened for the purpose of facilitating the radiation of heat from the target.

Both of these tubes are excellent for short exposures, with the heavy discharges obtained from induction coils operated with electrolytic interrupters.

A heavy target tube, made by the Volt-Ohm Co., is shown in figure 18. This tube is of the modified bi-anodic type, having a second electrode enclosed within a bulbous enlargement of the neck of the tube. In this tube the discharge passes very much more readily when the positive wire is con-

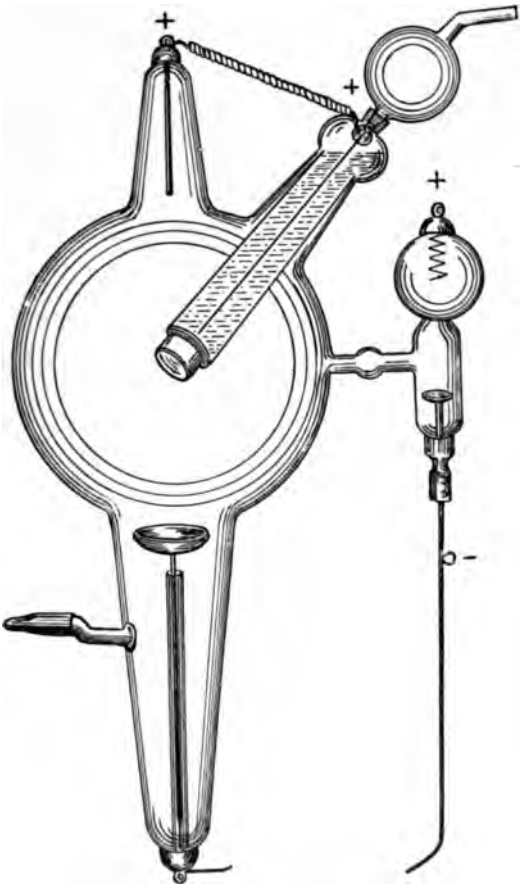


Fig. 17.—Müller's tube with water-cooled target.

nected with the auxiliary anode than when it is connected with the target. The target of this tube is made of a disc of copper $\frac{1}{4}$ of an inch thick, and faced with a thin sheet of platinum.

Double-focus Tubes.—The tubes described in the preceding pages are adapted for undirectional discharges, and are called single-focus tubes from the fact that they have one cathode and one focus point upon the target. With high-frequency apparatus and other exciting apparatus which give discharges

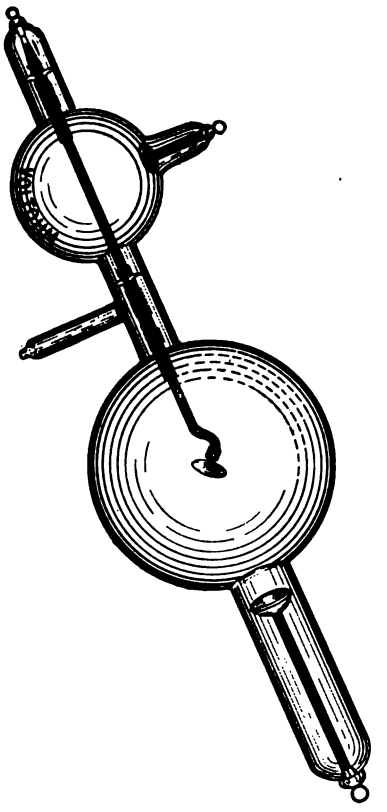


Fig. 18.—Volt-Ohm tube.

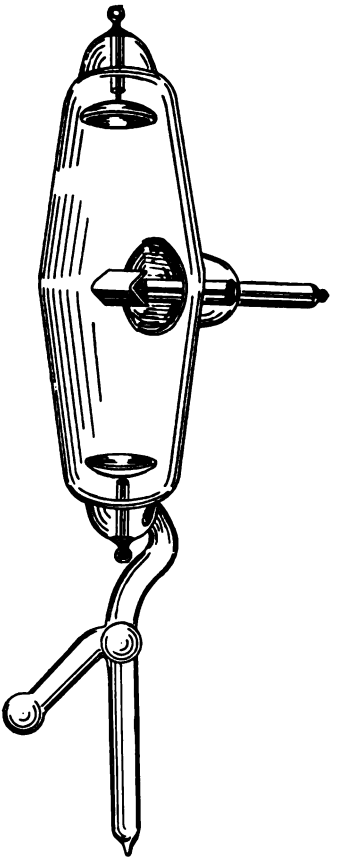


Fig. 19.—Thomson's double-focus tube.

alternating in direction, it is better to use a tube which operates equally well with the current flowing through it in either direction. Such a tube is shown in figure 19. The tubes are constructed so as to bring the focus points of the two concave electrodes as near together on the target as possible,

in order to secure good definition. In using such a tube the terminals of the exciting apparatus are connected with the two cup-shaped electrodes. With the changes in the direction of the exciting current each electrode becomes alternately the anode and cathode, and the *x*-rays originate from the target alternately from the focus points of these two electrodes.

Double-focus tubes have never been very satisfactory. It is impossible to secure with them as good definition as may be obtained with single-focus tubes. It is more difficult to regulate and maintain the vacuum, and blackening of the bulb is much more rapid than with single-focus tubes. At present they are used for therapeutic purposes when the available exciting apparatus produces alternating discharges.

Tubes for Therapeutic Uses.—Any of the ordinary forms of tubes may be used for therapeutic purposes. The selection of a tube for this work is a comparatively easy matter, definition is a matter of no importance whatever, and the regulation of the vacuum need not be so accurate as is necessary for fluoroscopic or radiographic work.

For treatment in cavities of the body—mouth, rectum, vagina, etc.,—a number of special forms of tubes have been designed. For treating the cervix uteri some operators employ the ordinary single-focus tube, placing it in line with a metallic speculum introduced into the vagina. With this method it is sometimes difficult to maintain the source of light in the proper relation with the speculum; the slightest change in the position of the patient being sufficient to cut off the rays from the affected area.

To avoid this difficulty Cossar, of London, has made a single-focus tube having a projecting ampulla which may be inserted into the vagina, and thus keep the tube in proper relation with the part. The walls of the tube are made of lead glass, which is comparatively opaque to the *x*-rays except at the end of the ampulla which comes opposite to the part under treatment, where the glass is thinner and of a composition which allows the rays to penetrate it readily. This tube is shown in figure 20.

Another difficulty of the single-focus tube and of tubes of

the type just described is due to the fact that the *x*-rays proceed in straight lines and cannot be appreciably reflected or refracted; consequently, it is impossible with them to apply the rays to parts which cannot be brought directly in line with the target, which is, of course, outside the body.

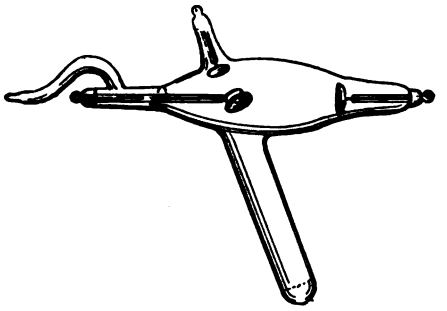


Fig. 20.—Cossar's tube for therapeutic uses.

In order to apply the rays directly to the larynx and certain other points upon which the rays cannot be thrown directly by the ordinary single-focus tube, I have devised some tubes in which the source of ray is at the end of a tubular projection which may be inserted within a cavity of the body, and from there send out rays in every direction. These tubes are shown in figures 21, 22, 23, and 24.

In the tube shown in figure 21 the target, T, is completely insulated and the anode, A, is placed at the end of a third tubular projection from the spherical part.

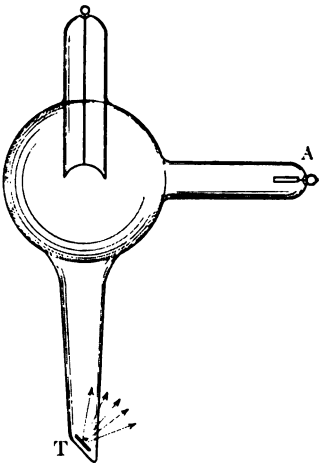


Fig. 21.—Tube for *x*-ray treatment of larynx, etc.

If the positive terminal of the exciting machine is connected to a ground wire, the tubular projection carrying the anode may be used as a handle and no shock will be felt either by the operator or the patient when the machine is in operation. This form of tube may be used without any special device for holding it, and the tubular projection carrying the target may be readily introduced through any of the common forms of vaginal and rectal specula, for applying the rays directly to the cervix, the vagina, the

rectum, or the prostate gland through the rectum. Since the outer surface is of smooth glass, it may easily be cleansed and sterilized. In the tubes for use in the mouth the glass is flattened behind the target. This enables the target to be brought very close to the soft palate, and in just about the position occupied by a laryngoscopic mirror. It is obvious that with the target in this position the rays will fall directly upon every part that can be seen in such a mirror. The tube shown in figure 22

Fig. 22.—Tube for *x*-ray treatment, for use with shield.

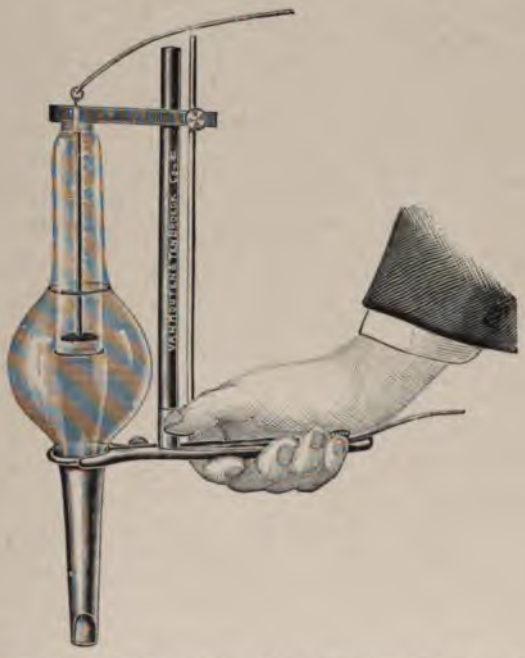


Fig. 23.—Handle, shield, short-circuiting switch, and tube.

is similar in appearance to the first one, but the target is provided with a connecting wire extending through the glass, and may therefore be made the anode. With this form of tube it is desirable to use the shield and handle shown in figure 23. The shield is a tubular hood of sheet-metal which slips over the projection carrying the target and performs several important functions. It protects the glass against breakage; it contains

an aperture through which the *x*-rays pass, and therefore limits the area exposed to their action; and, finally, it makes contact with the connecting wire of the target and completes the electrical connection between the target and the handle, which is, of course, connected to the positive terminal of the exciting machine and to ground.

The metal handle also supports the shield and the tube, and is provided with a switch so placed that it can be operated by the thumb, and arranged to ground the negative wire, thus short-circuiting the tube, stopping the *x*-ray, and at the same time making both wires safe to handle even while the exciting apparatus is in operation.

If a strong exciting current be used, the target ends of these tubes very quickly become hot. However, it should be remembered that with these tubes the source of *x*-ray is brought five or ten times closer to the part under treatment than is possible with the ordinary *x*-ray tube. Now, since the effects of the rays decreases approximately as the squares of the distance from their source, it is not necessary with these tubes to use a strong exciting current, or to make long exposures.

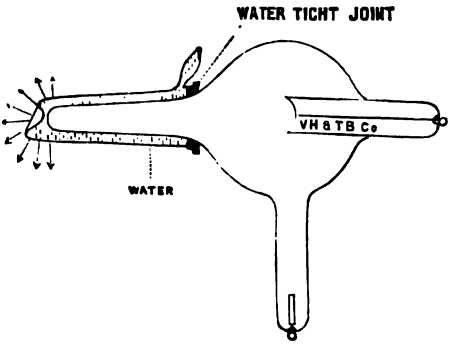


Fig. 24.—Tube for *x*-ray treatment of cervix uteri.

If an induction coil is used with this apparatus, a series spark gap of one or two inches should be included in the circuit to prevent short-circuiting the secondary winding of the coil when the tube is short-circuited by the switch at the handle.

Figure 24 shows another tube of this sort with modifications which adapt it especially for uterine and vaginal work. It will be noticed that in this tube, as in the old pear-shaped tube of Crookes, the cathode stream impinges not upon a metal target, but upon the glass wall of the bulb, which there-

fore becomes the source of the *x*-rays. There is also a considerable amount of heat developed at the point of impact of the cathode stream, and it is therefore necessary to cover the target end of the tube with a water-jacket in order to keep it cool.

As indicated by the arrows in figure 24, the rays emanate from the end of this tube in every direction—a condition which seems desirable in the treatment of most cases of cancer of the cervix of the uterus, and which is really the only essential difference between this tube and the original type shown in figure 21. If it is desired to limit the delivery of *x*-rays to any part of the area on which this tube is used, it can be done by removing the water-jacket and covering the corresponding part of the end of the tube with thick metal foil. The water-jacket may then be replaced and the tube is ready for use. A number of jackets of different shapes for different cases may be used upon the same tube.

CHAPTER III.

INDUCTION COILS, INTERRUPTERS, AND THEIR MANAGEMENT.

THE induction coil has probably been used more than any other apparatus for exciting *x*-ray tubes. It has the advantage that it is not materially affected by atmospheric changes, A fair-sized induction coil occupies comparatively small space, and it will deliver more energy than can be obtained from any static machine which has been built. For this reason it is particularly well adapted for radiographic work.

Induction Coil.—The induction coils sold for *x*-ray work all follow the same general lines, and differ only in size, in their relative proportions, and in the method of insulation. The coils are rated according to the length of sparks which may be obtained from them, and the smallest coils that may be used in practical work are rated at about 6-inch spark length. Such a coil has a core about 12 inches long, and about 1¼ inches in diameter; the coil complete weighs perhaps 30 pounds. Such a coil may be operated on about two cells of storage battery.

The largest coils that are made regularly for *x*-ray work are rated at 40 inches spark length. They are very massive machines weighing several hundred pounds, and have a length of core of about 7 or 8 feet. Between these two extremes there are a great many intermediate sizes. The ones most commonly used are rated from 10 to 18 inches spark length.

Winding of the Primary.—The primary windings in the coils of different makers vary considerably, and of course will be different according to the source of electrical energy with which they are to be supplied. In the coils which are to be operated from storage batteries it is customary to have but one layer of very coarse wire in the primary winding. This allows the coil to be operated with a comparatively small number of

cells. Coils which are to be operated from the 110-volt direct current lighting circuits often have in the primary winding as many as four layers, with as many as 500 or 600 turns of wire. Such coils will, of course, require smaller strength of exciting current for a given output, but the current must be supplied at a comparatively high electro-motive force.

In some of the newest types of coils there are four layers in the primary windings, and the ends of these layers are brought out to terminals in such a way that they may be connected in various combinations of series and parallel so that an equivalent number of turns of one, two, or four layers may be employed. This adjustment enables the coil to be adapted to

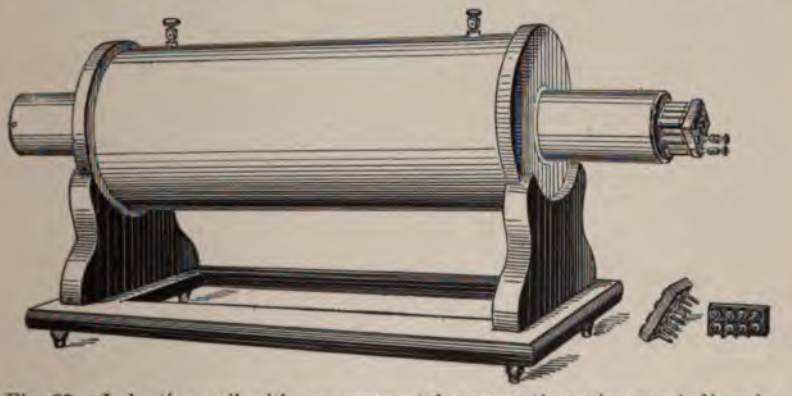


Fig. 25.—Induction coil with arrangement for connecting primary windings in series and parallel.

sources of current-supply of different potentials, and it also gives a certain amount of adjustment of the coil to suit the resistance of the tube which is used. Figure 25 shows a coil in which any connection of the primary is made by inserting various plugs in sockets on the end of the core.

Insulation between the Primary and Secondary.—Obviously it is necessary that the insulation between the primary and secondary windings must be of such a character that the sparks from the secondary will not penetrate it. In the majority of coils this is accomplished by using a hard-rubber tube which fits closely over the primary winding, and extends to the end of the core. The thickness of this tube will depend upon

the length of sparks which the coil is designed to deliver. For a coil of 10- or 12-inch spark length the rubber tube is ordinarily $\frac{3}{8}$ of an inch thick. For the larger coils it may be two or three times as thick. Insulating tubes of micanite, a mixture of mica and shellac, have been employed instead of hard rubber. These micanite tubes are perhaps a little less liable to be punctured by sparks than those of hard rubber. Some makers do not employ an insulating tube between the primary and secondary, but depend for this insulation upon the wax or other insulating material in which the secondary is imbedded.

Insulation of the Secondary Winding.—In the better coils the secondary is wound in a large number of vertical sections which are separated from each other by washers of paper or fiber. These sections are really flat helices, usually about $\frac{1}{8}$ of an inch long, and in a 10- or 12-inch coil there may be as many as 80 or 100 of them connected up in series.

In order to prevent discharges between the sections of the secondary winding it is necessary that they should be imbedded in some good insulating material. In most coils they are imbedded in a solid mass of wax. Some makers use oil for this insulation, and immerse the whole induction coil in a tank containing some heavy petroleum oil. The wax is to a certain extent liable to crack owing to changes of temperature, and the oil is very dirty and very liable to leak and cause trouble. In order to avoid these difficulties, some makers have imbedded coils in a viscous substance which does not become hard enough to be brittle, nor soft enough to flow, as does the oil. If a wax which has a very small temperature coefficient of expansion is used, the liability to cracking is very small, and on account of the greater cleanliness and convenience of the wax insulation it has been adopted by most makers. A few coils have been made with the sections of the secondary separated by insulating washers of vulcanite or glass, and spaced far enough apart so that the insulation afforded by the air is sufficient to prevent the sparks from passing between them. This construction has the advantage of allowing a burnt-out section to be readily replaced, but it has the great disadvantage of offering free access to moisture, which is

almost certain to collect and eventually impair the insulation between the windings. The wax insulated coils of the best makers are usually so satisfactory that there is no excuse for such a makeshift as this.

Insulation of the Secondary Terminals.—In some coils the ends of the secondary wire are brought out and connected with metal binding posts which are attached to the wooden framework of the coil. This is bad construction, especially for the larger coils, which are occasionally subjected to the unnecessary strain of giving 15- or 20-inch sparks. In almost every kind of wood there is a certain amount of leakage, and when it is subjected to high potentials in a damp atmosphere there may be enough moisture present in the wood so that this leakage will seriously impair the output of the coil. The better coils have the secondary terminals brought out through insulating sleeves to terminals supported on hard-rubber posts.

Breakdowns in Coils.—In order to secure efficiency in an induction coil it is necessary to bring the secondary winding as close as possible to the primary and core. In practice the distance between the ends of the secondary windings and the nearest parts of the primary and core is very much less than the sparking distance of the coil through the air, and the sparks are only prevented from taking the shorter path through the primary by the fact that the solid wax and rubber insulation offers very much more obstruction to them than the air.

The most common cause of breakdown of the induction coil is failure of the insulation between the primary and secondary windings, or between the adjacent sections of the secondary. When the spark passes through the wax or rubber insulation, the material is carbonized, so that its insulating properties are destroyed and the coil cannot deliver long sparks. These breakdowns are liable to occur when the insulation is unduly strained by causing the coil to deliver very long sparks, and when the coil has become overheated and the dielectric strength of the insulating material thereby reduced. Another cause of breakdown is in the cracking of the wax due to unequal expansion or imperfection in con-

struction. Sometimes in the winding there may be a short circuit between the different portions of the secondary. When this occurs, the current which circulates in the short-circuited portion not only reduces the output of the coil, but it is almost certain to cause considerable heating at this point, and render a puncture of the insulation easy. Sometimes when the wires from the terminals of the coil to the tube are allowed to lie across the cover of the coil, a spark will pass between it and the wires underneath. This is not so serious as a puncture of the insulating tube, or a short-circuit of the secondary windings, but it should, of course, be avoided.

The coils of the best makers are carefully tested before they are sent out, and if they are not subjected to bad usage they usually work satisfactorily for a number of years without repair.

In order to avoid breakdowns of the insulation it is well not to force the coil to deliver unnecessarily long sparks, and to be careful that the wires connecting the secondary and the tube do not come within sparking distance of the core, primary, or ground wire. In order to lessen strains on the insulation which may occur in case of grounding one terminal of the secondary, some makers connect the middle of the secondary winding to the primary.

Requirements of an Induction Coil for X-ray Work.—It was shown in a preceding chapter that for operating Crookes tubes for practical fluoroscopic and radiographic work potentials such as would produce sparks 1½ to 6 or 7 inches long are needed. It is safe to say that the whole range of tubes which are required in practice does not require a greater potential than that necessary to produce a spark through 8 inches of air. If we allow 2 inches for series spark gaps to cut off the inverse discharge, the maximum spark length necessary in a coil for practical *x*-ray work will be not more than 10 inches. In order to produce the powerful *x*-rays that are necessary for rapid radiographic work it will be necessary that the coil shall deliver a very powerful discharge at such spark length.

When the sparks from a coil appear thin and blue, the amount of energy represented is small. The coil for rapid radiographic

work should deliver thick yellow sparks, which have been called "fat," or "fuzzy," in contradistinction to the thin, wiry, crackling spark produced by discharges of small amount of energy. Unfortunately manufacturers of coils have given more attention to the length of the spark produced than to the amount of energy that may be obtained from them at potentials suitable for operating *x*-ray tubes.

The ordinary 8-inch coils easily deliver sparks 8 inches long, but do not deliver sufficient energy to get the best results from a Crookes tube. In the present state of affairs one must buy a coil which is rated at from 12 to 18 inches in order to obtain one which will deliver a 6-inch spark of sufficient volume for rapid radiographic work. Some *x*-ray workers have thought it necessary to use even larger coils, and have procured apparatus giving sparks of 25 to 40 inches in length. The manufacture of a coil which will deliver a spark 40 inches in length is a difficult matter, because of the extraordinary amount of insulation which is needed for such discharges, and which is quite unnecessary if the coil is to be used for operating *x*-ray tubes. The expense of constructing large induction coils increases in a much faster ratio than the length of spark delivered, and the size and weight are also out of proportion with the increase of spark length. It is manifestly absurd to build induction coils to deliver sparks 20 to 40 inches in length for use with Crookes tubes which ordinarily do not demand a greater potential than that represented by sparks 2 to 5 or 6 inches in length.

It has not yet been definitely determined whether as strong rays are necessary for therapeutic uses as are desirable in radiographic work, but at present it seems that an ordinary coil of 6 or 8 inches spark length will deliver sufficient energy in most cases. For radiographic work, however, it will be safer to employ a coil which is rated at 15 to 18 inches spark length.

Interrupters.—Differences of potentials in the terminals of the secondary winding of the coil are produced whenever there is a change in the strength of the primary current; and the more rapid the rate of change in the primary current, the

greater will be the difference of potential at the secondary terminal. When the primary current is increasing in strength, the secondary current will be in the direction opposite to that which is produced when the primary current is decreasing in strength.

The function of the interrupter is to break the primary current very suddenly so that this decrease in strength will be as rapid as possible. The increase in the strength of the primary current when the circuit is closed can never be nearly so rapid as its decrease when the circuit is opened. It is desirable that the primary current shall increase rapidly enough so that the core may be fully magnetized a great many times per second; but the increase should not be so rapid that the inverse discharge produced by it will be of high potential.

The secondary discharge at the break of the primary current is the one which is useful for operating *x*-ray tubes. The discharge at the make is in the inverse direction, and tends to have an undesirable effect upon a tube, impairing its vacuum, and introducing sources of *x*-ray at other points than the focus of the cathode upon the target. It is, of course, desirable that the secondary discharges through the tube shall be as frequent as possible, and it is therefore desirable that the interrupter shall be capable of breaking the primary current a large number of times per second, but that the rise of the current-strength when the primary circuit is closed shall not be rapid enough to cause strong inverse discharges. The closure of the primary circuit in all interrupters is practically instantaneous, and the rise of the current-strength in the primary depends upon the potential of the exciting circuit, and upon the winding of the coil. A high potential in the exciting current tends to make this rise more rapid, and in a coil of a small number of turns in the primary the current will rise more rapidly than in one which has a large number of turns. The undesirable inverse discharge will therefore be less with a coil having a large number of turns in the primary, but with such a coil the time required for magnetizing the core will be somewhat longer, and it will therefore be impossible

to obtain in a given time as many full discharges as with a coil of a few turns in the primary. The difficult problem in interrupters is to secure a perfectly sudden break of the primary current. Electrical circuits have a property which is somewhat like inertia, and which tends to prevent a sudden stoppage of the current flowing through them. When the contacts of the interrupter are separated, this tendency for the current to continue is liable to cause an arc to pass between the separated points. When this occurs, the current does not fall suddenly from its maximum. No interrupter for induction coils has yet been devised which is in all respects satisfactory.

There are many different forms of interrupters in use, and they may be conveniently divided into three classes: First, those in which the interruption is produced by the separation of two solid pieces of metal which are in contact; second, those in which the interruption takes place between mercury and a solid metal contact; and, third, electrolytic interrupters, in which the break takes place between two electrolytic conductors or between an electrolyte and a metallic conductor.

The first class includes the vibrating interrupters and rotary interrupters in which the break takes place between a metallic contact wheel and a brush bearing upon it.

Vibrating Interrupters.—One of the simplest forms of vibrating interrupter is that of Apps, which is shown in figure 26. The principle of its operation is practically the same as that of the vibrating hammer in an electric bell. The primary current is led through two platinum contact points, C, E, one of which is attached to a spring, S, carrying an armature of soft iron. This armature is arranged opposite the end of the core of the induction coil. When the current flows through the primary coil, the core becomes magnetic, attracts the armature, and pulls the contact attached to the spring away from the fixed contact, E, thus breaking the circuit. As soon as the circuit is broken the core demagnetizes, and the spring carrying the armature contact makes contact again with the fixed point. The tension of the spring which carries the armature contact point may be adjusted by means of a thumb-screw, T. This interrupter is very simple and reliable for coils of moderate

size, and is preferred to all others for operating coils for wireless telegraphy.

In another form of vibrating interrupter shown in diagram in figure 27 the movable contact is attached to a separate spring. The spring carrying the armature is provided with a hook arrangement which engages the contact spring and pulls the movable contact away from the one which is fixed after the armature has moved through a certain distance and has attained considerable velocity.

This type of interrupter has the advantage that the separation

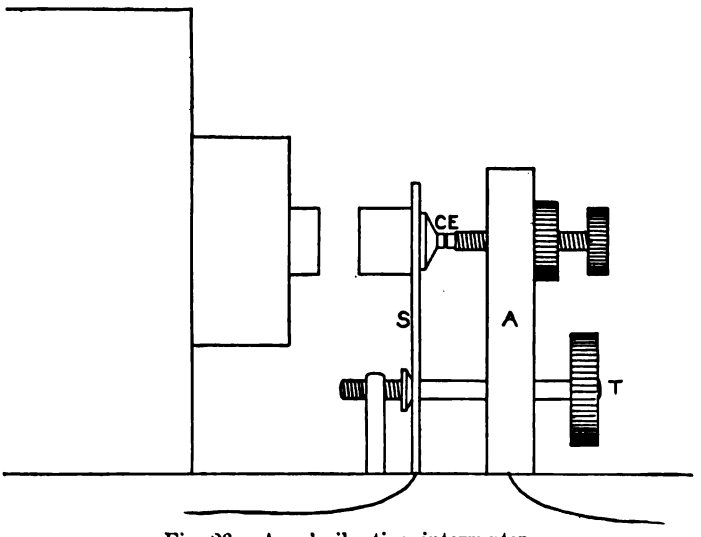


Fig. 26.—Apps' vibrating interrupter.

of the contacts is not made until the armature has attained considerable velocity, and is therefore somewhat quicker than in the simpler forms, like that of Apps. Vibrating interrupters embodying this idea are sold under many names, as the Vril break, hammer break, etc.

Both of these interrupters are operated by the magnetism of the core of an induction coil, and their operation will therefore be affected by changes in the strength of the exciting current of the coil. In order to avoid this difficulty, a number of makers have provided a separate magnet, operated by an

independent circuit, so that the operation will be independent of the strength of the primary current used. These interrupters nearly all embody the principle of the Vril or hammer break. The best vibrating interrupters have a considerable range in adjustment, and are fairly satisfactory for use with coils for radiographic work. With the smaller coils they are, perhaps, as satisfactory as any type of interrupter. They all have a number of inherent difficulties. They are more or less noisy, the contact springs are liable to break, the platinum points wear unevenly, giving rise to imperfect contact, and the heating at the platinum contact points may be sufficient to cause an incipient welding or sticking of the points together, so that the pull of the magnet does not separate them. When this occurs, the primary current is not interrupted, and it is liable to become unduly strong, to burn out fuses, and in other ways make trouble.

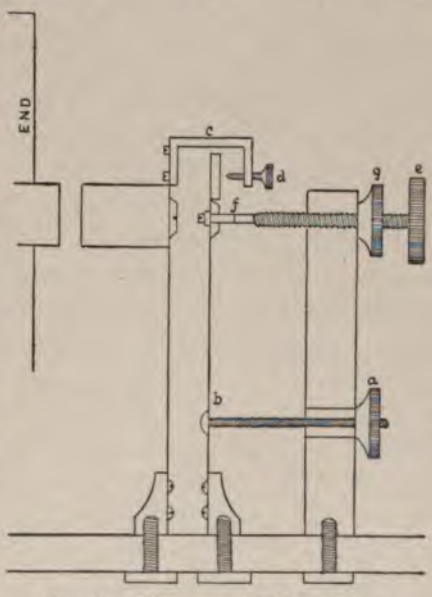


Fig. 27.—Diagram of Vril vibrating interrupter.

On account of the simplicity of these interrupters, their small weight, and the comparatively small space required for them, they are very useful in a number of situations. In portable apparatus they are almost indispensable.

In operating interrupters of this type it is necessary to adjust the contact points so that the vibrations of the armature are strong and even. The rapidity of the interruptions may be varied somewhat in some of the types by changing the amount of weight on the vibrating spring, thus changing its natural period of vibration. For radiographic work it will usually be

better to run such a vibrator at its lowest speed. The contact points must be adjusted so as to reduce as much as possible the sparking which occurs at the break, and they must be kept clean, bright, and even. A very small, thin file will be convenient for evening up the contact surfaces of these platinum points. If the interrupter sticks or stops vibrating, the primary circuit should be opened at the switch to prevent damage by excessive flow of current.

With the independent multiple vibrators the circuit which operates the vibrator magnet must be closed before the induction coil circuit is closed, and it will usually be necessary to put the armature in vibration by snapping it with the finger.

Rotary Interrupters.—Interrupters in which the separation of the contacts is effected by a movement of rotation (usually produced by an electric motor) are more positive in their action than the vibrating interrupters. In the vibrating interrupters the tendency to spark at the break is reduced by the use of platinum contact points, but in the rotary breaks the contact pieces are so large that it is not feasible to make them of platinum. They are usually made of brass and copper, and these metals have a tendency to flash or form arcs at the break, and thus fail to suddenly stop the current.

In order to prevent this arcing, some of these rotary interrupters have the contact wheel and brush immersed in oil. I have used for a number of years a rotary interrupter in which the sparking at the break is prevented by a packing of asbestos attached to the metal brush and filling up the space in which the arc would otherwise occur. This interrupter works very satisfactorily with current strengths up to 4 or 5 amperes from the 110-volt lighting circuit. With strong currents, however, this flashing at the break occurs even with the asbestos packing, and the action is not satisfactory. By making the contact wheel and brushes of certain alloys known as non-arcing metals the tendency to spark at the break is somewhat reduced. Most of the rotary breaks have not been satisfactory, and nearly all makers in this country have discarded them.

One of the German types of rotary interrupter which works in oil is shown in figure 28. In this apparatus the non-arcing

material is mercury amalgam of copper, the mercury being constantly supplied to keep the surface bright and well amalgamated.

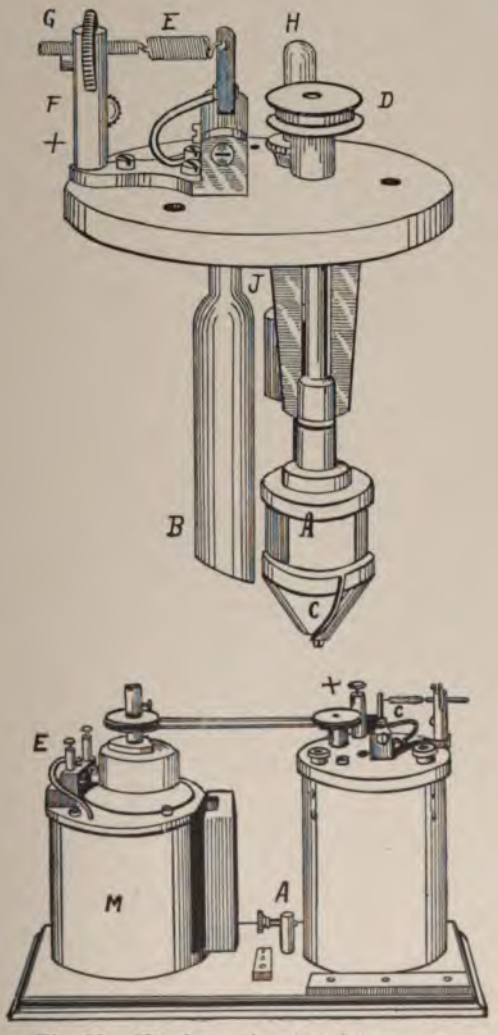


Fig. 28.—Hirschmann's rotary interrupter.

One of the best of the rotary interrupters is the one designed by Contremoulin, and made by Gaiffe & Co., Paris. This is really nothing more than a rotating contact wheel with brushes

operating under oil. One of the brushes is arranged so that by adjusting its position the relative duration of make and break of the primary current may be varied. If the range of this variation is sufficiently wide, no rheostat is required and the output of the coil may be reduced from the maximum to the minimum by simply changing the relative period of the make and break. This method of regulation is shown in diagram in figure 29. The current is led through the interrupter from one brush to the other, and the two metallic segments of the wheel are connected together. It is therefore necessary that both brushes be in contact with metallic segments in order that the current may pass. If the regulating brush is in the position shown at A, both brushes will come in contact with the metallic segments at the same time, and the current will flow through the coil for a maximum length of time. If the brush A is shifted to the position shown by the dotted line B, both brushes will be in simultaneous contact with the metallic segments during a very much smaller part of the revolution of the wheel; and if the regulating brush is carried to the point shown at C, the two brushes will never be both in contact with metallic segments at the same time, therefore no current will flow through the coil. Although these interrupters have not been used to any extent, it is but fair to say that they are probably quite as efficient as the mercury turbine breaks, although they have not been made to give the same frequency of interruption.

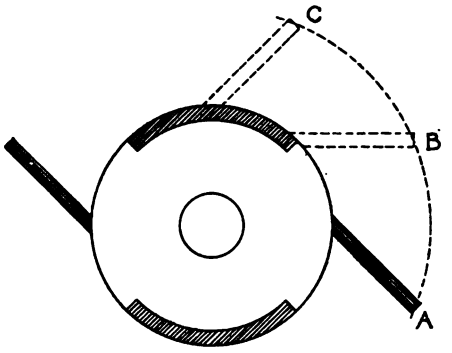


Fig. 29.—Diagram showing method of regulation in Contremoulin's interrupter.

With the coils which have a large number of turns in the primary winding, and which therefore do not require very strong exciting currents, these rotary interrupters are to my mind the best kind for use with the 110-volt direct-current

circuit. In nearly all induction coils, however, the primary winding is such that it is necessary to use strong exciting currents, and with such coils these interrupters are not so satisfactory.

Mercury Interrupters.—The use of mercury in interrupters has two advantages. Owing to the fact that the metal is a liquid, it makes very perfect contact; and owing to the fact that its vapor has exceedingly high resistance, the tendency to spark when the contact is broken is very much less than with many other metals.

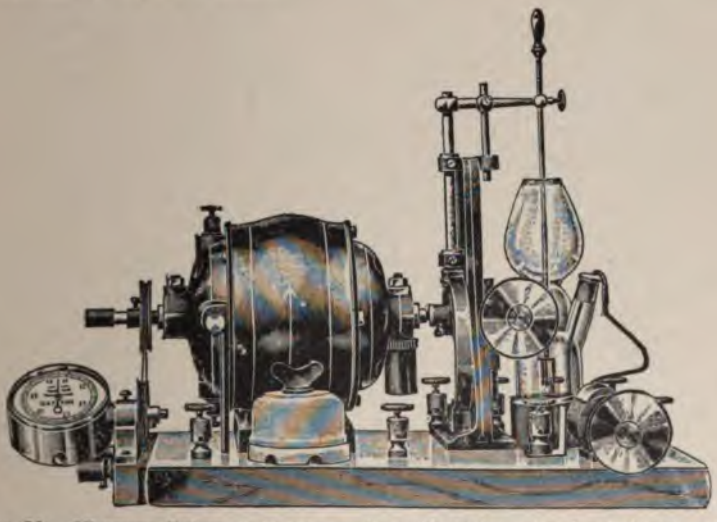


Fig. 30.—Mercury "plunger" interrupter with tachometer for indicating the frequency of interruption.

The mercury interrupters in common use are of two kinds. In one type the circuit is closed and opened by a metallic conductor which makes and breaks contact with the mercury by rapidly dipping below its surface and out again. In order to lessen the spark at the break, and to prevent the mercury vapor from reaching the air, a layer of oil or alcohol is usually floated on top of the mercury. This interrupter is usually operated by a small electric motor, and the frequency of the interruptions is varied by regulating the speed of the motor by means of a small rheostat. The relative period of make

and break is susceptible to some adjustment by raising or lowering the mercury cup. Obviously, the higher the level of the mercury, the longer will be the duration of contact with the moving conductor.

In one form of mercury dip interrupter the moving contact piece consists of a wire plunger which is connected by a crank on the shaft of an electric motor caused to oscillate rapidly up and down and to dip in and out of the mercury. Interrupters of this general type are made by most of the German manufacturers of *x*-ray apparatus. One of Max Kohl's mer-

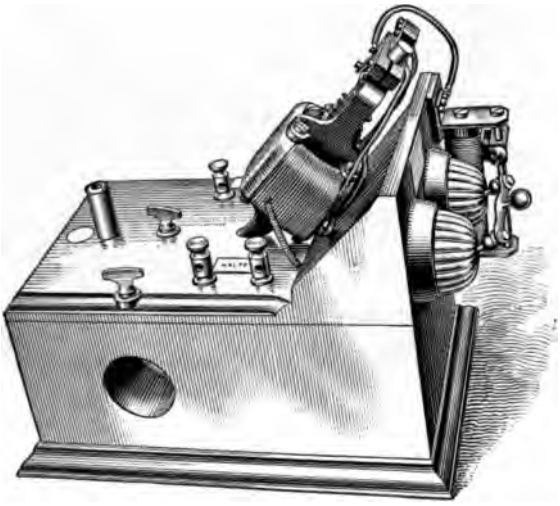


Fig. 31.—Mackenzie Davidson mercury interrupter.

cury plunger interrupters, as they are called, is shown in figure 30.

Dr. James Mackenzie Davidson has designed a mercury dip interrupter in which the moving contact piece is rigidly attached to the shaft of a motor which gives it a rotary motion. The motor shaft is inclined at an angle so that during part of its revolution the contact arm dips into the mercury. This interrupter is much simpler in construction than the plunger type, and runs much more quietly, owing to the fact that there is no reciprocating motion. The general appearance of it is shown in figure 31.

Turbine Interrupters.—In the turbine interrupters the closing and opening of the circuit of the coil is effected by a stream of mercury which is caused to play against a series of toothed metal conductors. Interrupters embodying this principle are made by several manufacturers of *x*-ray apparatus. In all of them there is a reservoir containing mercury, and a spiral screw-pump which raises the mercury from the reservoir, and allows it to flow through a nozzle against the metal vanes. In most of these instruments the position of the mercury jet is fixed, and the interruption is effected by rotating the toothed metal conductors against which the stream impinges. These teeth or vanes are triangular in shape with the points projecting downward, and by raising or lowering the mercury jet the duration of the contact between the mercury and metal vanes may be varied. In this way a considerable range of regulation of the coil may be effected.

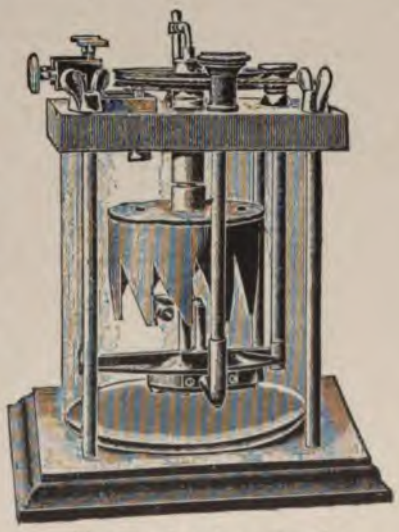


Fig. 32.—Levy's mercury jet interrupter.

The turbine interrupters of the various makers differ only in unessential points of mechanical construction. The one of Dr. Max Levy is shown in figure 32, and its construction is practically identical with that of the other German turbine interrupters. In all of these the break takes place in oil. For use with direct current circuits the turbine interrupter is belted to a small direct current motor the speed of which may be varied by a small rheostat and thus give different frequency of interruption.

When used with alternating current, the interruptions must always occur at a definite phase of the current wave, and the speed must therefore bear a fixed ratio to the frequency of the alternations of the current. This is accomplished by a

synchronous alternating current motor. Synchronous motors are not self-starting and when used for this purpose they are provided with a gear-wheel and crank by means of which they may be run up to full speed by hand at starting. These interrupters are arranged with an adjustment by which the interruptions may be produced at any desired period of the alternating current wave, which is, of course, constantly varying in strength. In this way a wide range of regulations may be obtained and no rheostat is necessary. The appearance of one of these interrupters is shown in figure 33.

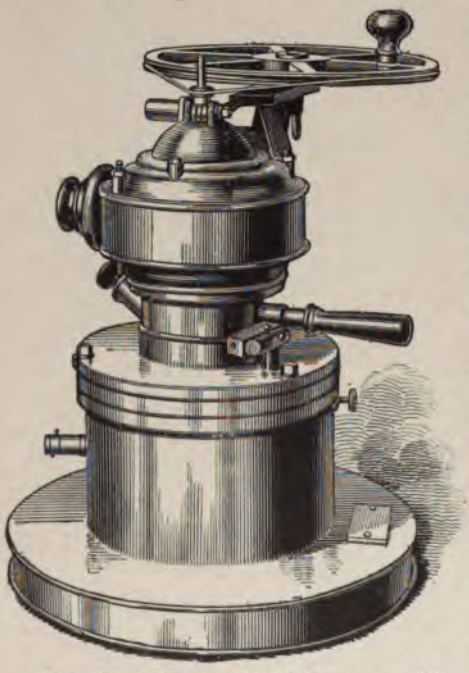


Fig. 33.—Mercury jet interrupter with synchronous motor for use with alternating currents.

In Dr. Cunningham's modification of the turbine interrupter the metallic vanes are fixed and the nozzle through which the mercury issues is rotated. The adjustment of the relative duration of make and break is effected by raising and lowering the vanes. The mercury stream is divided into two jets, and the contact is broken at two points instead of one, as in the other forms. Cunningham prefers not to use oil, but provides the rotating nozzle with an air-blast which is intended to blow out the sparks produced at the break. This interrupter is shown in figure 34.

In all mercury interrupters the mercury gradually disappears, and there is formed on the surface a scum which is made up of impurities and finely powdered mercury. In those types in which the break occurs in oil, the mercury vapor which is

produced at every interruption condenses and remains in suspension in the oil, forming a mud which settles over the surface of the mercury. In the plunger types this scum interferes with the contact between plunger and mercury. In some of the turbine interrupters in which oil is used the rapid rotary motion causes the oil to be sprayed out and damage furniture, carpets, etc. Sometimes the oil is vaporized and forms an explosive mixture with the air, and an explosion

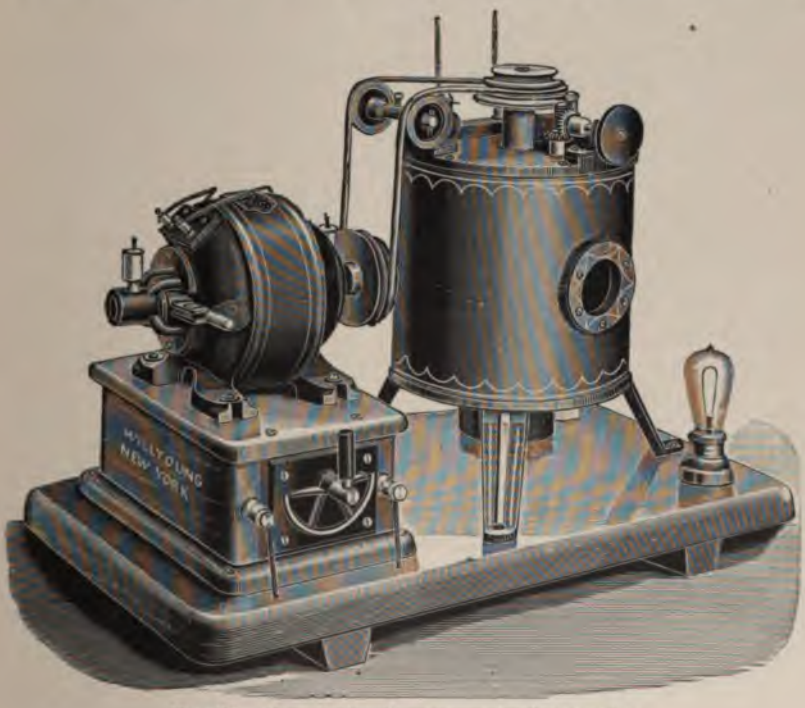


Fig. 34.—Cunningham's mercury jet interrupter.

may occur. This accident, however, is very rare, and is not liable to occur if care is taken to see that the interrupter does not become too hot, and that the level of the oil is sufficiently high. When the break occurs in the air, there is always a risk of the poisonous mercury vapor escaping into the room. The mercury becomes broken up into a fine powder which settles as flour on the surface, and which after a time interferes

with the action of the instrument. In all of these interrupters, then, it will be necessary to clean the mercury from time to time, and to keep adding a little more in order that the total quantity does not become reduced. With most of them it will also be necessary to replace the oil. In practice these interrupters require cleaning and adjusting about once a month, and except for this they require a very small amount of attention. It is therefore quite advisable to put such an interrupter in another room or a cellar at a distance from the induction coil to which it may be connected by a pair of wires.

In some respects these interrupters are more satisfactory than any other for general work. They give rapid rate of interruption, which may, of course, be varied within certain limits by changing the speed of the motor. In the turbine interrupters if the motor speed falls below a certain point, the rotary pump fails to lift the mercury high enough to produce the jet, and the circuit is not closed. This feature is really an element of safety, for no current can pass through the interrupter when it is at rest, and thus there is no danger in closing the induction coil switch before the interrupter is started. In case of an accident which stops the motor the circuit will remain open at the interrupter as soon as the speed falls below the critical point.

For radiographic work most coils operate more satisfactorily at a comparatively slow frequency of interruption, which gives exceedingly strong heavy sparks. For this work the mercury dip interrupter is better than the turbine interrupters as they are usually constructed. On account of the high frequency of interruptions which may be obtained with the turbine interrupters they give a very steady illumination of the fluorescent screen for fluoroscopic work.

Electrolytic Interrupters.—A great many years ago it was noticed by Spottiswoode, Plantè, and others that if a strong electrical current were passed through an electrolyte by means of two electrodes, one of which had a comparatively small area, the current would be interrupted by the collection of non-conducting gases over the small electrode. This action was studied very carefully by Paul Hoho, and was de-

scribed in detail by him in La Lumière Electrique, February, 1894.

The interrupting action is due to a film of non-conducting gas or vapor forming around the small electrode. The formation of this gas is apparently due partly to the vaporization of the liquid, and partly to electrolytic decomposition.

Although these phenomena were known long ago, the principle was apparently not applied to interrupters for induction coils until 1899, when Professor A. Wehnelt, of Charlottenburg, published a description of his interrupter. Wehnelt's interrupter consists of a jar of dilute sulphuric acid in which is immersed a lead electrode of considerable surface, and a small electrode made of a platinum wire sealed into the end of a glass tube and connected with the leading-in wire by means of a little mercury poured into the tube. When this arrangement is connected in series with an induction coil, and the current is caused to flow in such a direction that hydrogen is produced at the platinum electrode, very rapid interruptions of the current are produced, and powerful secondary discharges may be obtained from the coil. The details of this interrupting action are not fully understood, but it is certain that the inductance of the electrical circuit plays an important part in it.

With a Wehnelt interrupter the interruption occurs in practice only when the platinum electrode is made the negative pole. If the current is sent through it in the opposite direction, interruptions may, under certain conditions, be obtained, but the platinum will be very rapidly destroyed. Sometimes after a few minutes' use this interrupter may stop because of a bubble of gas which collects over the platinum electrode and prevents the liquid from making contact with it. The bubble may be removed by shaking the electrode, or by reversing the direction of the current for an instant, and the operation will commence again. If the interrupter has been in action for some time, the liquid becomes hot, and the interrupting action becomes unsteady and sometimes stops. It has been proposed to keep the liquid cool by immersing in it a coil of lead pipe through which cold water may be circulated. In

practice it is better to use a large jar containing such an amount of liquid that the rise of temperature is slow, and having such a large surface exposed that the loss of heat from the liquid is facilitated. In the operation of this interrupter certain insoluble lead salts may be formed from the lead electrode, and by remaining in suspension in the liquid interfere somewhat with the action of the instrument.

The fact that with this interrupter the interruptions occur ordinarily only when the platinum electrode is made the cathode makes it possible to employ it for operating an induction coil from an alternating circuit, and obtain unidirectional discharges from the secondary. The interruptions occur, of course, only while the current flows in such a direction that hydrogen is liberated at the platinum electrode. The current waves in the opposite direction produce no interruptions, and no sparks at the secondary.* The discharges which are produced from an induction coil in this way are very satisfactory for exciting *x*-ray tubes, but it is impossible to obtain as much energy from the coil as it will give with the direct current and the same interrupter. Moreover, with the alternating the platinum wears away very rapidly and causes considerable annoyance and trouble. With the direct current the wearing away of the platinum is so little that it is not a serious objection. When the alternating current is used with this interrupter, the reversals in direction of the current tend to free the platinum point from any bubbles of gas which tend to collect, and its action is very much steadier, and may be prolonged for a greater period than is possible with the direct current.

The frequency of interruptions with this apparatus will depend somewhat upon the strength of the current passing through it, and upon the amount of surface of platinum exposed to the electrolyte. In a common form of the instrument the platinum electrode is in the form of a wire which is enclosed in a porcelain tube, and the amount of its projection below

*The rate of change of the strength of current of commercial alternating current systems is not rapid enough to produce long sparks in an ordinary induction coil.

the tube into the liquid may be adjusted by means of a screw. In this way it is possible to adjust the apparatus for interruptions of various frequencies, and to compensate for the wearing away of the platinum when the alternating current is used. This interrupter is shown in figure 35.

One of the best forms of Wehnelt interrupter is one which was devised by Dr. Crane, of Kalamazoo, and which is especially well adapted for use with alternating currents.

In this interrupter the platinum electrode consists of a short piece of platinum wire of large diameter placed in the end of a glass tube from which it is separated by a short length of rubber

Fig. 35.—Wehnelt interrupter with screw adjustment for regulating the amount of platinum exposed to the liquid.

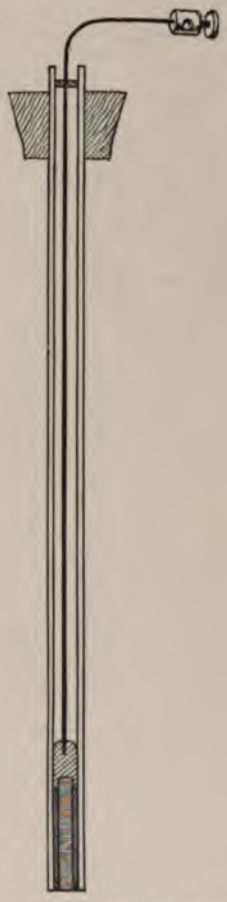


Fig. 36.—Crane's platinum electrode for Wehnelt interrupter.

tubing. The connection with the platinum electrode is made by means of a copper wire and a little mercury poured in the tube to make connection between the wire and the platinum. Only the end of the platinum wire is exposed to the liquid, and

in practice the glass tube, the rubber tube, and the platinum wear away at about the same rate, so that such an interrupter may be used with the alternating current for a considerable time without adjustment. (See Fig. 36.)

An excellent form of Wehnelt interrupter for use with the alternating current was described by Messrs. Gaiffe and Galliot

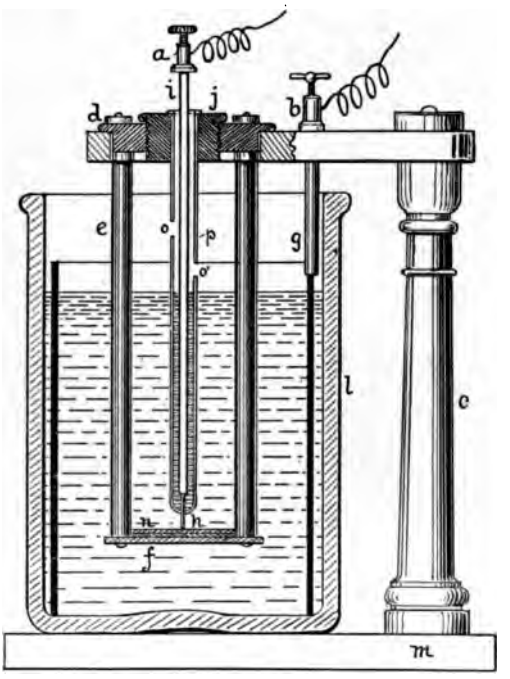


Fig. 37.—Gaiffe and Galliott's modification of Wehnelt interrupter for use with alternating currents.

in the Archives of the Röntgen Ray for July, 1902, and is shown in figure 37.

It will be seen that in this interrupter the platinum electrode slips easily through a porcelain tube and rests upon an insulating support a short distance beneath it. As the end of the wire wears away, a fresh portion of the wire is fed through the tube by gravity, and thus an approximately constant amount of surface is exposed, regardless of the wear. In order to adjust the frequency of interruptions the distance between the

end of the porcelain tube and the insulating support can be varied by an adjusting screw, and thus expose more or less of the platinum electrode to the liquid. This is perhaps the most satisfactory type of Wehnelt interrupter for use with the alternating current.

In the New York Electrical Review, May 4, 1899, I described a form of interrupter * which is similar in appearance to that of Wehnelt, but which differs from it in some important essentials. A diagram of this interrupter is shown in figure 38. It consists of a jar containing dilute sulphuric acid, within which is a cup of insulating material perforated by a small hole. Lead electrodes are placed in the outer jar and in the insulating cup.

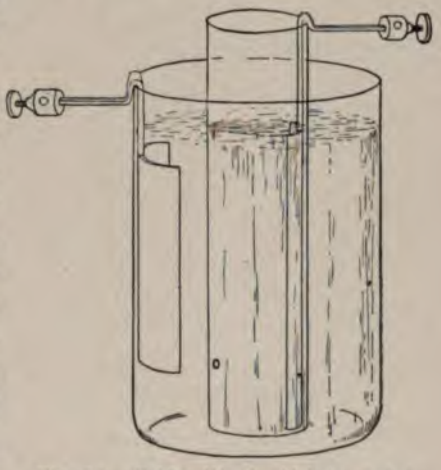


Fig. 38.—Caldwell's liquid interrupter.

When the primary current of an induction coil is passed through this apparatus, there is comparatively little heating of the liquid except in the aperture connecting the two chambers, where the current density is very large on account of the small area of the aperture. At this point, therefore, sufficient heat is developed to rapidly vaporize the liquid, and bubbles of steam which form break the connection between the liquid in the inner jar and that in the outer jar. As soon as the current is broken the heating stops and the two portions of the liquid come together again, completing the circuit. The frequency of the interruptions will depend upon the strength of the current, the size of the aperture, the resistance of the electrolyte, and to some extent upon the inductance of the circuit. An arrangement for varying the frequency of interruption by adjusting the size of

* This type of interrupter was invented independently by Dr. Simon, of Berlin, and was published by him in Germany about the same time.

the aperture was described by the author in the New York Electrical Review, May 11, 1899, and is shown in the diagram in figure 39. In this arrangement the aperture is at the bottom of the inner cup. It is partly closed by a pointed rod of non-conducting material which protrudes through it. By raising or lowering the protruding point the cross-section of the annular aperture between it and the cup may be varied, and thus the frequency of interruptions adjusted through a wide range. Mr. A. A. Campbell Swinton devised a screw adjustment for the regulating rod of this interrupter.

This interrupter is not so susceptible to changes in the strength of the exciting current, or to changes in the temperature of the liquid, as the Wehnelt. It will therefore remain in operation somewhat longer, and admits of a wider range of adjustment of the exciting current. The action of this interrupter is quite independent of the direction of the current through it, therefore when employed for operating induction coils on the alternating current circuit the current will be broken at each alternation and the secondary discharges will alternate in direction. Such discharges are not suitable for operating single focus tubes, and the interrupter is therefore not adapted so well for alternating currents as the Wehnelt interrupter. With the alternating current it is possible to use double focus tubes, but these are usually unsatisfactory except for therapeutic purposes.

Fig. 39.—Diagram showing method of regulating size of aperture in liquid interrupter.

Dr. Ruhmer, of Berlin, has devised a modification of this interrupter in which the two portions of the liquid are contained in separate jars which are clamped together and which communicate with each other through a small aperture in a porcelain disc between them.

With the electrolytic or liquid interrupters there is produced a mixture of oxygen and hydrogen, which if confined may explode. They should therefore not be enclosed in a tight

box, but freely ventilated so that the gas may escape. They give off acid fumes which are disagreeable. If they are to be used for long periods, it will be well to have them placed in a cellar, or some point distant from the operating-room, and connected to the exciting apparatus by wires. The liquid commonly employed in them is dilute sulphuric acid, sp. gr. 1200; and this, of course, will cause serious damage to carpets and furniture in case it becomes accidentally spilled. The electrolyte is slowly evaporated by the high temperature produced, and must occasionally be renewed, perhaps once in three or four months. With most induction coils these interrupters operate better without a condenser. They require comparatively little attention, and they enable a greater amount of energy to be taken from a coil than can be obtained with any other type of interrupter. They are, therefore, especially adapted for the most rapid radiographic work, where the exposure will not be longer than a few seconds. They may be operated continuously for half an hour or more, but when this is done there is considerable change in the temperature of the liquid, gas collects, and the action is not so satisfactory. Therefore they are not well adapted for continuous operation of induction coils, although they may be used for this purpose if several interrupters are provided, and the connections are changed from one to the other, thus giving each one an interval of rest.

Condensers.—In order to lessen sparks which occur at the point of interruption of the primary current of the induction coil it is necessary, with all interrupters except those of the liquid or electrolytic types, to use an appliance called a condenser.

This condenser consists of a number of sheets of metal foil laid up together with sheets of insulating material between them. The alternate metal sheets are connected together, forming two sets of conductors of large surface which are insulated from each other by intervening sheets of insulating material, and therefore have large electrostatic capacity. When the terminals of such a condenser are connected to the contact points between which the primary current is broken, the dis-

charge which would otherwise cause an arc to pass between these points, and impair the sharpness of the interruption, passes into the condenser and stores up in it an electrical charge.

These condensers are made in a variety of forms, but in nearly all of them the metal sheets are of tinfoil. In some of them the insulating material between the layers of tinfoil consists of waxed paper; in others it is thin sheets of mica. The dielectric properties of mica are better than those of paper, and the mica condensers are a little more satisfactory in their operation. They are also much lighter, and smaller for a given capacity than the condensers with paper insulation, and are therefore preferable when the question of weight is to be considered. Well-constructed paper condensers, however, answer very well, and they are very much cheaper than mica condensers.

In order to obtain the best effects of the condenser with large coils it is necessary to be able to adjust its capacity to suit the strength of the exciting current and frequency of interruptions. This is usually accomplished by a small switch having several points by means of which the number of sheets of tinfoil connected in the circuit may be varied.

Rheostats.—If the induction coil is operated from a storage battery circuit, it will usually be possible to obtain satisfactory regulation of the output by varying the number of the cells in the circuit. A certain amount of regulation may also be made by adjustment of the interrupter.

If the coil is to be operated from an electric lighting circuit, it will be necessary to have in series with it an adjustable rheostat for controlling the strength of the current supplied to it. The regulation of the current strength is effected by a sort of switch mechanism which cuts in the circuit more or less of the resistance wire of the rheostat. Rheostats suitable for this purpose are made by a number of manufacturers of electrical apparatus, and most of them are very good. A rheostat will, of course, be supplied by the dealer who supplies the induction coil, but it is a good idea to examine it carefully to see that it has sufficient resistance to reduce the secondary discharges until they are just strong enough to excite a small

tube, to see that there are a sufficiently large number of contact points so that accurate regulation may be obtained, and, finally, to see that the carrying capacity is great enough so that the rheostat does not become overheated with a run of five or ten minutes at the full capacity of the coil. As a measure of safety it is a good idea to place a stop on the rheostat at the point which allows the maximum current which will be used to flow. This will prevent sending unduly strong currents through the coil by accident. If the electrolytic interrupters are to be used, however, it will be necessary at times to get all the rheostat resistance out of the circuit, and such a stop will then be very inconvenient.

The use of a rheostat when the exciting current is obtained from a storage battery will sometimes admit of closer regulation than can be obtained by varying the number of cells, and has the advantage that all the cells of the storage battery will be discharged to the same extent.

With those interrupters in which the regulation is effected by varying the relative periods of make and break of the primary current the rheostat is, of course, unnecessary, but will often be a convenience.

Switches.—It is usual to provide the induction coil with some means for reversing the direction of the current through the primary coil. The simplest arrangement for this purpose is a double-pole, double-throw knife switch. This switch serves not only for opening and closing the circuit, but controls the direction of the current through the coil according to the position in which it is closed. It is convenient to have the connections made so that when the switch is closed the handle points in the direction of the positive terminal of the secondary coil. If the coil has two or more separate windings in the primary, the same kind of switch may be used for connecting them either in series or parallel. In the German coils this is usually effected by some plugging device, such as was shown in figure 25.

Fuses.—In order to prevent a dangerously large current from flowing through the coil through any accident there is usually included in the circuit a piece of wire of low melting-point, which becomes fused and opens the circuit when the current

becomes too strong. Such devices are commonly known as fuses, and are used everywhere for protecting all kinds of electrical circuits. Sometimes the fuse is mounted on the base of the coil, or sometimes at the wall terminal of the electric lighting circuit. It will be convenient to have near the *x*-ray machine a fuse which may be readily replaced, and which is of such size that it will burn out before the most distant fuses in the lighting circuit. This will often save annoyance and the trouble of hunting in cellars or other places to find where the fuse has blown out. A supply of extra fuse wires or plugs should be kept on hand so that when one burns out it may be quickly replaced.

Meters.—Although not a necessity, it is often a great convenience to have in circuit with the induction coil an ammeter which indicates the strength of the exciting current. The ammeter readings are useful because they bear a more or less close relation to the amount of energy supplied to the tube, though, to be sure, this relation is not very close unless the rate of interruption, the relative period of make and break, and the vacuum of the tube remain the same when the different readings are made. When these conditions can be kept fairly constant, the ammeter readings are of considerable value in therapeutic work for estimating the strength of the discharge of the coil or the intensity of *x*-rays. Records of these ammeter readings enable the same treatment to be repeated with a fair degree of accuracy.

The energy of a single discharge from the induction coil bears a close relation to the strength of the exciting current at the instant it is broken to produce such a discharge. It must be remembered that the current which operates an induction coil is rapidly changing in strength from zero to a maximum, at which point it is broken, and following such break is a long or short period of rest before the circuit is closed again. It is the value of this maximum strength which is reached just before the circuit is broken that determines the energy of the secondary discharge. The ammeter does not register the value of this maximum current, but in a more or less imperfect manner integrates the current curves and

indicates approximately the average current strength, including the periods of rest following each break when the current strength is 0. It will be obvious, therefore, that in order to use the ammeter readings as a measure of the energy supplied to the tube it will be necessary that the frequency and character of the interruptions remain unchanged.

The ammeters usually employed for this purpose are the ordinary direct reading instruments which are intended for measuring steady currents. The accuracy of these instruments when used for measuring intermittent currents, such as pass through an induction coil, is not very great, but it is sufficiently good for practical purposes. If the greatest accuracy is required in these current measurements, the only practical direct reading instrument is the hot wire ammeter, which measures equally well currents of any form—continuous, alternating, or interrupted. It may be shown that such a hot wire ammeter connected in series with an ordinary direct current meter of the magnetic type will give the same reading as the direct curent meter when a steady current is flowing. If the current is rapidly interrupted, the reading of the direct current meter will be somewhat less than that of the hot wire meter.

A voltmeter will be useful for determining the condition of storage batteries; but if the current supply is from a lighting or power circuit, it is quite unnecessary, because the potentials of these circuits are fairly constant. In recording the energy supplied to the *x*-ray tubes which are used in therapeutic work some physicians have given not only the ammeter readings, but the readings of the voltmeter connected across the terminals of the source of current supply. At first thought it might seem that the two readings must bear a fixed relation to each other. This would be true if the current was perfectly steady. This, however, is not the case, and the voltmeter reading in connection with the ammeter reading does to a certain extent give an indication of the character of the interruptions of the circuit, and may at times be useful for obtaining a given adjustment of the interrupter. In radiographic and fluoroscopic work, however, the voltmeter reading is comparatively unimportant.

Induction Coil Installations.—The ordinary induction coil outfit consists of an induction coil, vibrating interrupter, condenser, switch for opening and closing the circuit, and sometimes a rheostat, mounted together on one base. It may be placed upon a table and connected with a storage battery, or an electric lighting circuit, or other source of electrical energy. Such outfits are sold by nearly all the manufacturers of *x*-ray apparatus. Figure 40 shows a common form of this apparatus.

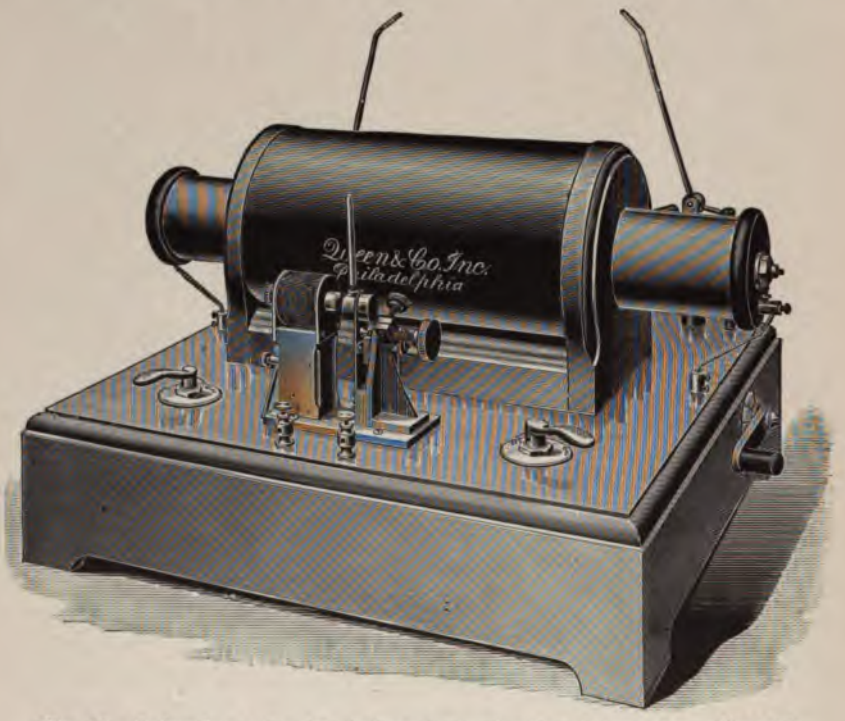


Fig. 40.—Induction coil with independent vibrating interrupter, adjustable condenser switches, etc., mounted on base.

In the more elaborate outfits it is usual to have the coil and controlling apparatus mounted separately. The common practice in Germany is to fasten the coil firmly to the wall of the room at a height of 6 to 8 feet from the floor and to mount the controlling apparatus, meters, etc., upon a small table which may be moved around the room at the convenience

of the operator. Such an installation is shown in figure 41. The advantage of this arrangement is that the controlling devices may be placed in such a position that the operator may have them at hand while he is using the fluoroscope. One of the disadvantages of the method is that the high potential wires from the coil to the tube must be long. They have greater electrostatic capacity, there is more danger of obtaining

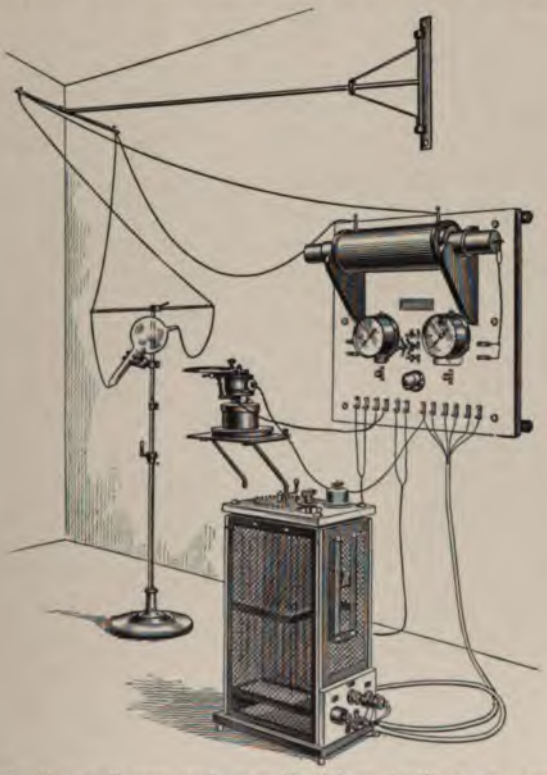


Fig. 41.—Induction coil mounted on wall with controlling apparatus on movable stand.

a shock from them, and the brush discharges from them are more noticeable than when coil and tube are brought close together.

I prefer to mount the coil on a small table provided with castors so that it may be moved as close as possible to the tube-holder and tube. The meters, controlling devices, etc., are

then mounted firmly upon a switchboard or wall-plate and connection between them and the coil is made by flexible conducting cords. With this arrangement the lead wires between the coil and the tube are very short, and the liability of leakage and accidental contact with them is reduced. A firm, solid support for the meters is better than a movable apparatus which is subject to jar and mechanical shocks.

An *x*-ray outfit that is to be employed for a variety of purposes—radiographic work, fluoroscopic examinations, and *x*-ray

Fig. 42.—Switchboard with movable coil.

treatment—should be supplied with at least two interrupters, with switching or plugging devices for changing from one to the other. For the fastest radiographic work it will be well to employ interrupters of the liquid or electrolytic type. These interrupters, however, are not suitable for continued use, such as may be required for long fluoroscopic examinations or therapeutic applications of the *x*-ray. For such work as this the mercury interrupters and the ordinary vibrating interrupter are preferable. These types of interrupters are better adapted

for long runs, and with them a wider range of regulation of the exciting current is possible.

The arrangement of switchboard and coil at the Edward N. Gibbs *X*-ray Laboratory is one which facilitates the changing the connections of current supply, interrupters, etc. This outfit is shown in figure 42. The switchboard carries, in addition to the meters, a rheostat, a condenser, a series inductance coil, all of which are adjustable by means of the three hand-wheels shown. The connection of the various types of interrupters is made by means of a plug and flexible cord which is connected to two binding posts at the lower right-hand corner of the board. Several different sources of exciting current are available, and these may be selected by means of a similar plug and flexible cord connected at the upper right-hand corner of the board. Underneath the board is a little cupboard for the liquid and electrolytic interrupters. This cupboard connects directly with a flue which provides a suitable outlet for the fumes and gases. The cupboard is so well enclosed that the noise of the interrupters is not offensive.

Portable X-ray Apparatus.—Occasionally it is necessary to make radiographs at the bedside of a patient who cannot be moved. These cases are almost invariably those in which the injury is in the thicker parts of the body, and powerful apparatus will therefore be necessary.

The ordinary induction coil outfit for office use is not a readily portable machine, and the static machine is, of course, quite out of the question for work of this kind. The only thing that may be used with convenience is an induction coil outfit of moderate size which is arranged to be easily transported without risk of damaging it. A considerable experience in moving different *x*-ray outfits, one of them weighing 300 pounds, has led me to the conclusion that the best arrangement of a portable outfit consists in dividing it up into a number of packages none of which shall weigh more than 40 or 50 pounds.

The simplest portable induction coil outfit for radiographic work will consist of the induction coil, interrupter, controlling devices, tube-holder, two tubes, plates and plate-holder, and

storage battery. In order to avoid exceeding the weight limit above mentioned and to carry a coil which is large enough

Fig. 43.—Portable induction coil and portable liquid interrupter closed, ready for transportation.

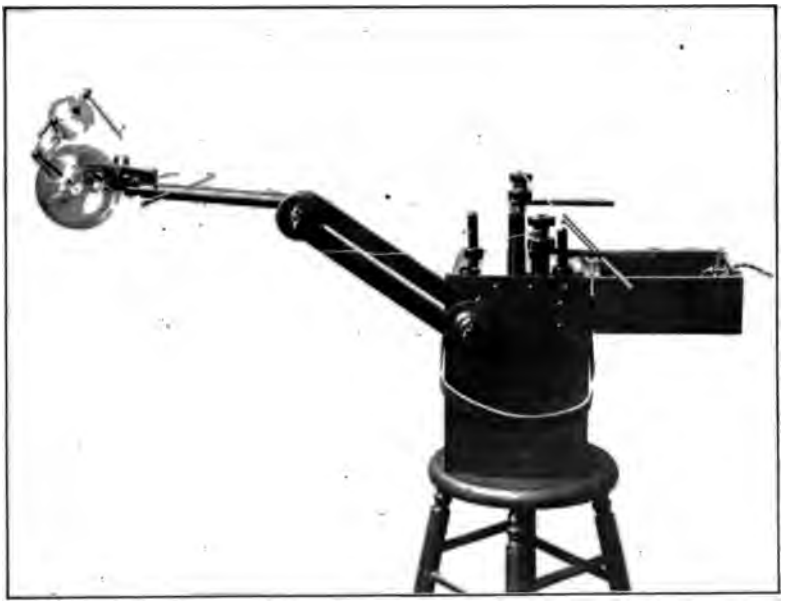


Fig. 44.—Portable induction coil ready for use, showing tube-holder and tube.

for the most difficult work it will be necessary to have at least three packages; and since it will take two persons to carry

these, it is just as well to have the outfit divided into four packages. If the outfit is to be operated from a storage battery, these packages will be as follows: (1) induction coil with tube-holder; (2) interrupter, condenser, and connecting cords ; (3) plates and plate-holder, and two tubes; and (4) storage battery. If the outfit is to be operated from an electric lighting circuit or from a 100-volt electric automobile storage battery, the arrangement may be as follows: (1) induction coil, with tube-holder; (2) portable liquid interrupter with 100 feet flexible cord and suitable plugs for connecting with a lamp socket or with the charging socket of the automobile; (3) plates, plate-holder, and two tubes.

Fig. 45.—Portable induction coil with case opened.

By following out the principles of design mentioned in the early part of the chapter I have succeeded in obtaining a coil sufficiently powerful for radiographing any part of the body, and which weighs but a little more than 40 pounds. Even with such a light coil as this, in order to avoid exceeding the weight limit of 50 pounds in any package, it is necessary to mount the condenser and interrupter separately. The induction coil is therefore mounted in a box with adjustable tube-holder, adjustable series and multiple spark gaps, spools for carrying the lead wires of the tube, and a switch for connecting the two windings of the primary in series or parallel. This coil with the above accessories is shown in figures 43, 44, and 45. For use with exciting current at 100 volts or more the primary windings are connected in series. When they are connected in parallel. the coil works very well, with six storage cells and a vibrating interrupter.

A portable vibrating interrupter with adjustable mica condenser for use with this coil is shown in figure 46. A portable

electrolytic interrupter with controlling switches is shown in figure 43. The tubes, plates, and plate-holders are carried in a wooden case with a carrying strap. The arrangement of this

Fig. 46.—Portable condenser with vibrating interrupter.

Fig. 47.—Portable coil with vibrating interrupter and condenser.

portable coil and tube-holder is such that it may be conveniently placed upon a chair at the side of a bed, and support the tube in any position over the patient, the plate being placed, of course, underneath.

Portable induction coils of somewhat smaller size and having the condenser and vibrating interrupter mounted with them are made by Queen & Co., Willyoung, and others. One of these coils is shown in figure 47.

CHAPTER IV.

STATIC MACHINES AND THEIR MANAGEMENT.

THE static machine, although it is large, clumsy, and noisy in operation, and is subject to serious disturbances from atmospheric changes, has been used extensively for exciting Crookes tubes for *x*-ray work. It is claimed that various electrical discharges which may be obtained from these machines have useful therapeutic properties, and long before the discovery of the *x*-ray hundreds of such machines were sold to physicians in this country for use in electrical treatments. When the *x*-ray was discovered, the man who owned a static machine had only to purchase a fluoroscope and a Crookes tube and tube-holder in order to have a fairly good *x*-ray outfit. A few men have obtained excellent radiographs with the static machine, and there are some who prefer it to every other apparatus for exciting *x*-ray tubes.

Although the static machine is not so well adapted for radiographic work as the induction coil, it has been a very satisfactory apparatus in the hands of many physicians who employ the *x*-ray for fluoroscopic examinations, for therapeutic applications, or perhaps occasionally for minor radiographic work.

On account of the steadiness of its discharge it is very well adapted for exciting Crookes tubes for fluoroscopic work. There is much less heating of the target of Crookes tubes when they are excited by a static machine than when operated by a coil. Lighter and cheaper tubes may therefore be used with a static machine, and their deterioration will be much less rapid, the life of the tube being very much increased. The cost of tubes is quite an item of expense in running an *x*-ray outfit, and this advantage is well worth considering. The operation of a static machine is, for most people, somewhat easier than that of an induction coil with its troublesome interrupters.

Modern influence machines, or so-called static machines, do not, as is often supposed, generate electricity by friction, but by what is known as electrostatic induction, or the influence of an electrical charge upon bodies which are brought into its vicinity. In most of these influence machines there are a number of circular glass plates which are arranged to revolve in close proximity to two sets of stationary armatures made of paper and metal foil. High potential charges are maintained upon the two armatures, one set being positive and the other set negative. Portions of the revolving glass plates as they approach the charged armatures have their electrical condition disturbed by the influence of these charged armatures. While under the influence of the armatures a rearrangement of the electrical charge on the surface of the revolving plates takes place through toothed brushes, or combs, called neutralizing combs, which connect the opposite sides of the revolving plates which are under the influence of the two armatures. When these portions of the revolving glass plate have passed out of the influence of the armatures, and away from the neutralizing combs, they possess free electrical charges, which are then removed by the collecting combs, and lead out to the terminals of the machine.

The two types of influence machines which are commonly used are those of Holtz and Wimshurst. In the Wimshurst machine the revolving plates are arranged in pairs and the charges on the different portions of one plate of a pair act inductively on corresponding portions of the other pair in the manner just described. Nearly all of the static machines sold in this country are either the Holtz type, or a modification known as the Toepler-Holtz. In England and France the Wimshurst machines are more in use, and in Germany one rarely sees a static machine. Nowhere are they made in such large sizes, or is the mechanical construction so good, as in this country.

For therapeutic purposes the Holtz machine is preferred to the Toepler-Holtz because its discharge is steadier and less painful, and because it gives longer sparks. For *x*-ray work there is very little difference in the efficacy of the two types.

With the Holtz type the armatures are liable to become discharged when the machine stops, and it is customary to employ a very small Wimshurst or Toepler-Holtz for giving the armatures the initial charge which is necessary to put the apparatus in operation. Both the Wimshurst and Toepler-Holtz machines are self-charging.

The influence machines operate better with tubes of high resistance such as are suitable for fluoroscopic work than with the low resistance tubes which are usually desirable for radiographic work. One reason for this is that the electrical charges of the armatures are collected from the revolving plates, and the potential of these revolving plates will depend somewhat upon the resistance of the tube which is connected with the terminals of the machine. If the tube is of high resistance, the difference of potential at the terminals of the machine will be great, and it will be easy to maintain high potential charges in the armatures, but if a low resistance tube is connected across the terminals of the machine, the difference of potential between the armatures will be reduced to a greater or less extent. The output of the static machine, other things being equal, varies directly with the difference of potential upon the armatures, which act in this respect somewhat like the field magnets of a dynamo.

The charge which is derived from the revolving plates for maintaining the potentials in these armatures is, in the Holtz machine, collected at about the same point that the collector combs are connected with the terminals of the machine. If a tube of low vacuum is used, the potentials of these terminals will fall, and of course the potential of the armatures will fall correspondingly. The machine will then be working at a disadvantage, it will absorb less energy from the motor and will deliver less electrical energy to the tube. In the Toepler-Holtz machine the charge for the armatures is collected from the revolving plates before their charge has been reduced by the collectors connected with the terminals. In this type of machine, therefore, the potential of the armatures is not quite so much affected by the potential at the terminals, and it is a little better adapted for use with tubes of low resistance.

I have found in the Holtz machine that it is possible to prevent to some extent this reduction of the armature potential by turning the collector combs of the terminals beyond the point where the charge for the armature is collected, so that

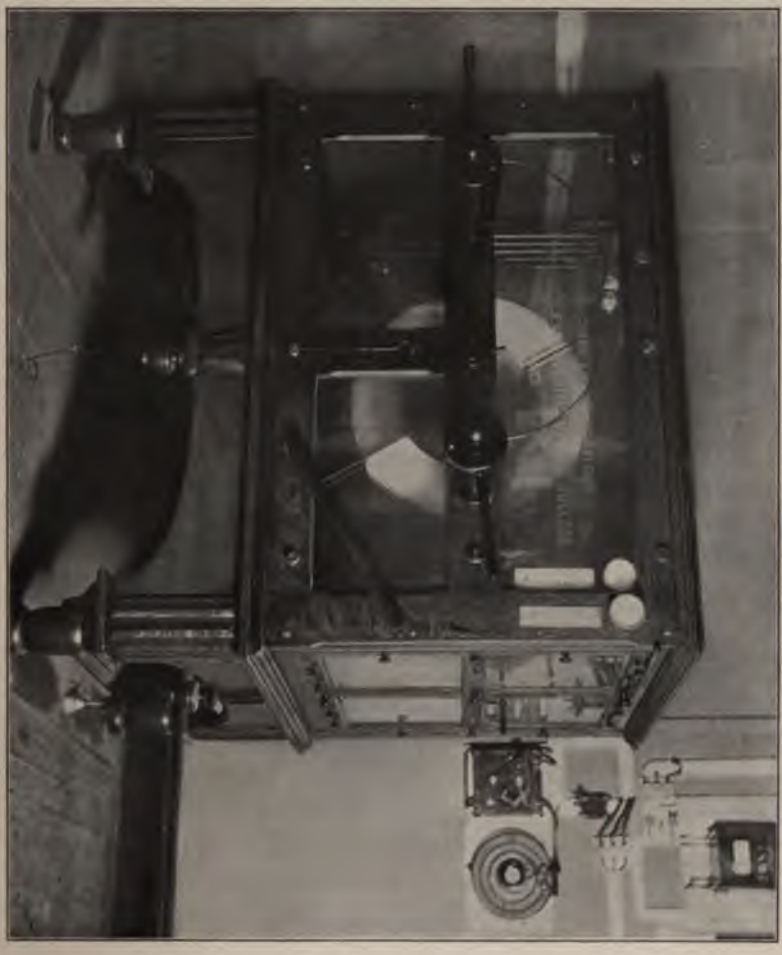


Fig. 48.—Holtz machine with twenty-four revolving plates.

the armature collects its charge first from the plate before the potential has been reduced by the collector combs. This change can be made without trouble in many of the Holtz machines, and although it materially reduces the length of spark which it is possible to obtain, it increases the power of the

Fig. 49.—Ordinary type of Holtz machine.

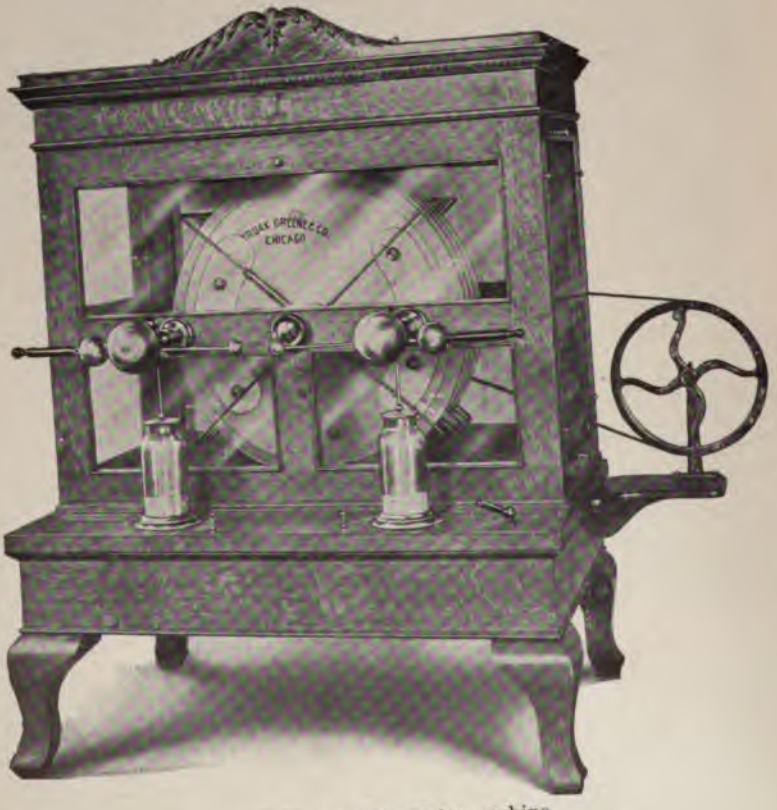


Fig. 50.—Toepler-Holtz machine.

discharges at such potentials as will be used for operating *x*-ray tubes.

A Holtz machine made by Waite & Bartlett and having 24 revolving plates, and having the collector combs arranged in this manner, is shown in figure 48. The ordinary types of the Holtz and Toepler-Holtz machines are shown in figures 49 and 50. A Wimshurst machine made by Newton & Co., London, is shown in figure 51.

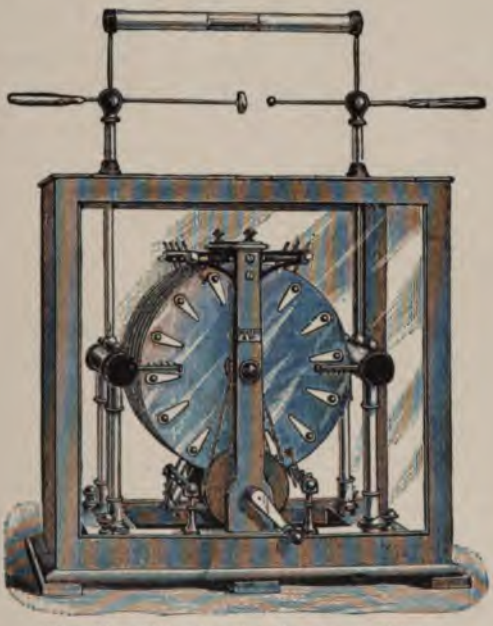


Fig. 51.—Wimshurst influence machine.

Size of Machine.—The influence machines usually sold in this country have from 6 to 16 revolving plates, from 26 to 32 inches in diameter. Some machines have been made with a large number of small plates, and others with few plates of very large diameter. Those of Dr. Williams and Dr. Rollins have revolving plates of thick glass about 6 feet in diameter.

The generating capacity of a static machine bears a fairly close relation to the area of revolving plates exposed to the inductive action of the armatures. Longer sparks may be

obtained from machines with plates of large diameter, but what is needed for *x*-ray work is not long sparks, but powerful discharges at a difference of potential which would produce sparks of only a few inches, or very much shorter than the sparking distance of the ordinary static machine. The mechanical construction of a machine having sufficient surface for producing such discharges is made easier by having a large number of plates of small diameter than with a few plates of large diameter. The best diameter for the revolving plates is about 30 inches. This is the size which has been adopted by most of the makers. A static machine for *x*-ray work should have not less than 10 or 12 revolving plates 30 inches in diameter. Such a machine will be large enough for fluoroscopic examinations of any part of the body. Machines of 16 or 20 plates will be more powerful and somewhat shorter radiographic exposures may be obtained with them, but for this work the largest static machine that can be built will be much inferior to a fair-sized induction coil.

Hard-rubber and Mica Plates.—On account of the fragile nature of glass some makers have made the revolving plates of hard-rubber, or of a mixture of mica and shellac, with the object of enabling higher speeds to be obtained with safety, thus giving greater output for a given number of plates. There is abundant proof that with the increase of speed there is increase in output, but it is doubtful whether the advantages of reducing the number of plates in this way are sufficient to compensate for the troubles incident to running such a machine at a very high rate of speed. Moreover, there is always some question about the lasting qualities of the substances which have been used as substitutes for the glass plates.

Hard-rubber deteriorates very rapidly, and is quite unsuitable, although a large output may be obtained from a hard-rubber plate machine when it is new. Mica plate machines have been run at a speed of 2000 revolutions per minute. The ordinary speed for a glass plate machine having revolving plates 30 inches in diameter is not more than three to four hundred revolutions per minute.

Regulating the Discharge.—The usual method of controlling

the output of the static machine is by varying its speed. If the machine is operated by a direct current motor, the speed of this motor may be varied within wide limits by means of a small speed-regulating rheostat. A small alternating current motor such as would be employed for this purpose runs at a constant speed, which is determined by the number of poles in the field magnet of the motor, and the frequency of alternations in the power circuit. When such a motor is used, the speed of the static machine may be regulated by means of a variable friction gear device connected between the motor and the machine. One of these arrangements is shown in figure 52.

Fig. 52.—Friction speed controller for influence machine.

They are, of course, wasteful of power, but for running small machines will be satisfactory. Sufficient regulation of the speed for ordinary purposes may be obtained by the use of cone pulleys, though of course such an arrangement is not convenient because the machine must be stopped and the belt rearranged in order to obtain a change of speed. With most static machines, however, there is no necessity for speed regulation in the operation of *x*-ray tubes. It will usually be found that the maximum amount of energy which can be obtained from the machine at full speed will not be too much.

It has been proposed to control the output of the static machine without changing its speed by shifting the position of the neutralizing combs.

Enclosing Case for Static Machine.—In order to protect the machine from dust and moisture it is necessary to enclose it in a case which should be as nearly dust- and air-proof as possible. The case is ordinarily made of a framework of wood with large glass panes in it. In order to prevent leakage of the discharge the case should be so large that there will be a distance of not less than 8 or 10 inches between it and the nearest part of the revolving plates. In most of the static machines made in this country the front and back of the case form supports for the shaft. This is not the best possible mechanical construction, but it has been adopted by nearly all makers. Therefore in selecting a machine it is well to see that the parts of the case which support the bearings of the shaft are heavy and strong enough for this purpose. The sides of the case should be readily removable to facilitate getting at the inside for changing the drier, or cleaning or airing the machine. It will be convenient to have in one side of the case a small door which may be quickly and easily opened and closed. Such an arrangement would very materially facilitate the changing of the drier in the machine, especially in damp weather, when it is undesirable to let the case remain open for any length of time. It is important that the case should be accurately fitted and made of well-seasoned wood, which will not shrink or warp with the result of producing cracks which allow dust and moisture to enter, or perhaps even throwing the bearings of the shaft out of alignment.

Ozone and Nitrogen Oxids.—In the operation of the machine some of the oxygen of the air within the case is converted into ozone. At the same time there are formed certain compounds of the oxygen and nitrogen in the air which are more or less corrosive and somewhat hygroscopic. When these substances collect in considerable quantities, the efficiency of the machine is seriously impaired. It is therefore a good idea occasionally to open the case and thoroughly ventilate it for an hour or two.

Disturbing Effects of Moisture.—When there is enough moisture in the air so that it is liable to condense upon the different parts of the machine, it interferes very seriously with its operation. During the summer months and in damp places it will usually be necessary to employ some artificial means for keeping the inside of the case dry. The ordinary method is to place within the case one or two vessels containing about ten to twenty pounds of calcium chlorid which has been thoroughly baked. After a while this calcium chlorid will become saturated with water, and useless. Therefore it must be removed occasionally and baked out again for several hours. Lime has also been used for this purpose, and it is claimed that this substance takes up not only the moisture but the compounds of oxygen and nitrogen. If lime is employed, the vessel containing it must be tightly covered with cloth of fine mesh in order to prevent the dust of the slaked lime from getting out into the case, where it would be carried around by the air-currents and electrical charges. It has been recommended that a jar of calcium chlorid and a jar of lime be used at the same time.

Sometimes instead of drying the air in the case it is warmed by means of incandescent lamps or an electric heater. Of course, when the air is warmed it has a greater capacity for moisture, which therefore does not become condensed out on the machine and destroy its insulation. Usually it is more satisfactory to dry the air. In damp weather it is a good idea to wipe off the terminals and discharge rods of the machine, especially the hard-rubber insulating sleeves supporting the terminals, with a very warm, very dry rag, in order to remove all of the moisture. The metal parts of the terminals should always be kept clean and bright and free from dust or corrosion.

Oiling the Machine.—It is, of course, necessary in any machine which runs at three or four hundred revolutions per minute to keep the bearings well oiled. In the static machine the oil at the ends of the bearings which project within the case is especially liable to become sticky and gummy. It is necessary occasionally to flush out the bearing with some thin oil which will dissolve out the hardened machine oil. With a static

machine having ball bearings the oiling, of course, will not have to be done so frequently as in those having the ordinary bronze bearings. The bronze bearings, although they require more attention, are to my mind preferable because they are not so noisy.

Series Spark Gap.—Every static machine which is to be used for *x*-ray work should be provided with some sort of an adjustable spark gap which may be placed in circuit with the lead wires to the Crookes tube. If the tube is of proper vacuum its terminals may be connected directly with the terminals of the static machine. If the tube is a little too low in vacuum, it may be made to work better by inserting a small series spark gap on one side or the other, perhaps on both sides. It will be found that some tubes work better with the gap on the negative, and others with the gap on the positive, side. The series spark gap also lessens the tendency to brush discharges and sparking from the lead wires and other exposed metal parts of the circuit. The arrangement for producing this spark gap may be a simple sliding metal rod with a ball terminal, which may be fastened to the hard-rubber handle of the discharge rods of the machine, but it is better to use some modification of the Williams multiple spark gap, which is described more fully in the chapter on fluoroscopy.

Polarity.—Before connecting the Crookes tube to a static machine it is, of course, necessary to determine the polarity of its terminals. This may be done in various ways. The quickest way is by observing the character of the sparks which pass between the discharge rods. After a little practice one will readily recognize from the appearance of the sparks which pole is negative and which is positive.

If sparks about four inches long are allowed to pass, it will be noticed that at one terminal they seem to proceed from a point or comparatively small area and spread out and strike the other ball at a number of points more widely separated. The former is the positive and the latter the negative pole.

CHAPTER V.

FLUOROSCOPY.

X-RAY examinations can be made with the fluorescent screen much more easily and quickly and cheaply than with radiographs. For examinations of the thorax the use of the fluoroscope has the great advantage that the movements of respiration do not interfere, as is the case in making radiographs of these parts. Another advantage is that the parts under examination may be examined from a great many different points of view. It should be remembered, however, that the fluoroscopic picture will never be so accurate and reliable as the radiograph, and that satisfactory radiographs may be obtained of many parts of the body where fluoroscopic examinations are of no value. Moreover, in certain cases the fluoroscopic examination may be misleading.

Limitations of Fluoroscopic Examinations.—In partial fractures, or even complete fractures where there is little or no displacement, the fluoroscope usually fails to show the condition, but a good radiograph almost invariably reveals such conditions. Sometimes a foreign body which cannot be shown by the fluoroscope may be very easily found and located with the radiograph. Fragments of fine needles or small pieces of glass may not be located with a fluoroscope, but are very readily found with the photographic plate. In a case of a bullet wound from a toy pistol held very close to the skin the fluoroscope showed the bullet plainly enough, but the radiograph showed, in addition, pieces of wadding which were carried into the wound, and which were not shown by the fluoroscope. In cases of fracture, dislocation, and foreign substances in the body it will usually be advisable to supplement the fluoroscopic examination by at least one radiograph.

Apparatus for Fluoroscopy.—For the purpose of fluoroscopic examinations there is not much room for choice between the

induction coil and the static machine. If the coil is used, it is advisable to employ an interrupter which may give not less than 20 to 30 breaks per second in order to obtain a steady illumination of the screen. The steady illumination of the tube which is produced by the static machine is especially adapted for fluoroscopic work. Fluoroscopic examinations require ordinarily much longer exposures than are necessary for making radiographs. A tube which may be operated by a powerful coil for a few seconds with safety may become overheated or rendered useless if the same degree of excitation is prolonged for a sufficient length of time to make a careful fluoroscopic examination. With a static machine there is much less need for watching the tubes to guard against overheating, and most tubes will have a much longer life than if excited by a coil.

For fluoroscopic examinations of almost every part of the body it is well to choose tubes of considerably higher penetration than would be best for making radiographs of the same part. It is, of course, a great advantage to be able to adjust the penetration of a tube so as to bring out most clearly the part under examination. The tubes with vacuum regulators are very desirable for this work.

Series Spark Gap.—It has been noticed that the character of the *x*-rays delivered by a tube may be varied by introducing an adjustable spark gap in series with it. The effect of this spark gap varies with different tubes. With some tubes an increase in penetration is produced when a spark gap is introduced on the positive side, while in others the same effect is obtained with the spark gap on the negative side. In others the effect is the same in either position of the spark gap.

A very efficient series gap arrangement is that of Dr. Williams, which is shown in figure 53, the essential part of which consists of two rows of brass balls mounted a short distance apart on an insulating support provided with a sliding rod by means of which any number of gaps between the balls may be put in circuit. The brass balls are about $\frac{3}{4}$ of an inch in diameter and the interval separating them is about $\frac{1}{8}$ of an inch, about 15 to 18 balls being used in each row. One of these arrangements is connected to each terminal of the exciting apparatus.

and the sliding rod by which adjustment is made may be manipulated by means of cords with handles extending down where they can be reached by the observer while using the fluoroscope. In operation the discharge passes as a spark from each ball to the next one through an air gap of about $\frac{1}{8}$ of an inch. By varying number of balls in circuit a very wide, and at the

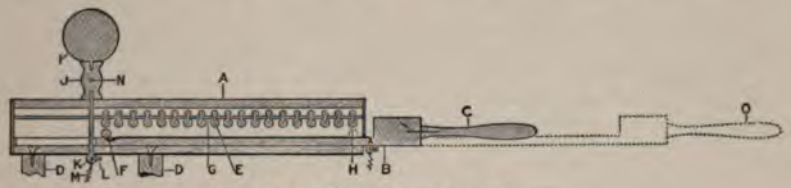


Fig. 53.—Williams series spark gap.

same time delicate, adjustment of the penetration may be secured. The widest range of regulation will be obtained when the vacuum of the tube is very low, so low that it is practically worthless when excited in the ordinary manner. The arrangement is much more effective with static machines than with induction coils. With the induction coil it is necessary to

Fig. 54.—Wilkinson's spark gap.

connect Leyden jars in the circuit across the terminals in order to obtain the best effect of the spark gaps.

No adequate explanation has been given for the penetration effects produced by this apparatus. In the hands of Dr. Williams it has been used with splendid success in fluoroscopic examinations of the thorax, and also in radiographic work.

A serious objection to its use is the very disagreeable noise

produced by the sparks passing across the gap. Another disadvantage is that it requires an exciting apparatus capable of delivering much longer sparks than are necessary with tubes of proper vacuum.

A modification of the Williams spark gap, which is somewhat simpler in construction, and which is arranged to be attached to the tube-holder, has been devised by Mr. Wilkinson, and is shown in figure 54.

Fluoroscopes and Fluorescent Screens.—Although there are a great many salts which fluoresce under the action of the *x*-ray, there are only two which have been extensively used in fluorescent screens for practical work. These are barium-platino-cyanide and calcium tungstate. The barium salt gives a yellowish-green fluorescence of great brilliancy, and is the one preferred for fluoroscopes. The tungstate of calcium gives a bluish-white fluorescence, not so brilliant as that of the barium salt, but which, on account of its color, has greater action on photographic plates, and is therefore used in intensifying screens for radiographic work. Tungstate screens are used also in fluoroscopes, and are preferred by some operators. This preference may in some cases be due to a partial color-blindness.

The ordinary fluorescent screen consists of a piece of cardboard coated on one side with a thin layer of crystals of the fluorescent material, and supported in a wooden frame. Such a fluorescent screen is convenient where demonstrations are to be made to a large number of people at once. Such screens must be used in a darkened room, and the light produced by the fluorescence of the glass of the tube should be cut off by covering it with a piece of black silk cloth or enclosing it in a box.

A fluoroscope consists of such a screen mounted in the end of a box or hood, one end of which may be fitted closely to the eyes, and which shuts out any external light from the screen. In the ordinary fluoroscope the hood is made of thin wood covered with cloth, as shown in figure 55. Some fluoroscopes have a hood made of a leather bellows so that the distance between the screen and the eye of the observer may

be adjusted. This is, of course, a convenience, though in practice not an important one. In the ordinary fluoroscope the pasteboard back of the fluorescent screen is very liable to mechanical injury; and when it is used in examinations of injuries where there are open wounds or pus, it is very liable to absorb moisture and become damaged in this way. For such work as this it is very desirable to cover the screen with a smooth non-absorbent material which can be readily cleansed. This protects the screen against injury and also lessens the danger of carrying infection from one patient to another. Sheet celluloid $\frac{1}{16}$ of an inch thick answers very well for this purpose. It offers considerable protection against mechanical injury and it can be easily cleansed and sterilized. It offers so little obstruction to the x-rays that it does not impair the efficiency of the fluoroscope. Considerations of cleanliness suggest also the use of some non-absorbent material instead of cloth for covering the hood of the fluoroscope.

Fig. 55.—Fluoroscope with removable screen.

Fluoroscopes with hoods of hard-rubber are better in this respect. Sometimes the face of the fluoroscope screen is covered with a thick plate of glass. This arrangement has several advantages. It protects the crystals from dust, and to a certain extent it prevents them from drying out, especially if the back of the screen is covered with celluloid. Finally, to a great extent it protects the observer against the x-rays which pass through the screen, although it does not obscure the light due to the fluorescence. It has the disadvantage of making the screen heavy and clumsy.

In order to prevent the secondary rays from affecting the screen, and possibly masking the useful fluorescence, it has been suggested to line the hood with sheet-metal. This result

is, of course, accomplished effectively by the use of a heavy lead glass in direct contact with the screen.

It has been noticed that fluorescent screens deteriorate with age. This may be due partly to loss of water of crystallization, and it is said to be due also to chemical changes which are produced by the action of the powerful *x*-rays. Screens should never be left near a steam radiator, or in any place where they are subjected to hot dry air. It is also recommended that they be kept, when not in use, in metal cases to protect them

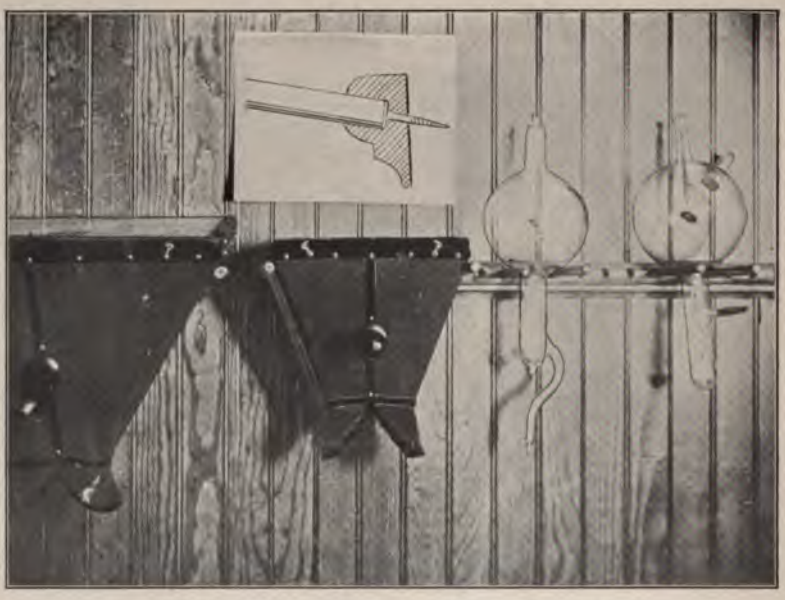


Fig. 56.—Rack for supporting tubes, fluoroscopes, etc.

from the action of the *x*-rays. The ordinary fluoroscope when not in use should be suspended with the open end down to prevent collection of dust upon the screen. A convenient rack for supporting a fluoroscope in this manner is shown in figure 56.

The barium screen when it is new has a greenish-yellow color, but after a while the greenish tinge disappears and the color becomes a light canary yellow. Usually when this condition is reached the screen does not fluoresce so brilliantly as when it is new, though sometimes this is not the case. Different

screens vary much in their keeping qualities. Some of them may be very efficient after three or four years' use. When a screen has deteriorated, or become injured in any way, it may be returned to the makers, who will allow for the fluorescent material which it contains.

It will be well to have at least two fluoroscopes of different sizes. For examinations of the thorax a large screen not less than 11 × 14 inches is useful for showing the whole area. When examinations are to be made of a small area, it will be found much more satisfactory to use a fluoroscope with a small screen, for the reason that in such a case the illumination of the screen beyond the part under examination only tends to dazzle the eyes. In the ordinary fluoroscope there is usually a frame of wood about one inch wide between the margin of the screen and the edge of the hood. In certain situations this prevents placing the screen in the most convenient position: for example, when the fluoroscope is placed at the front of the neck, under the lower jaw, the screen of such a fluoroscope cannot be placed as high as may be desired. For such work as this it is therefore well to have a small fluoroscope in which the fluorescent material extends quite up to the edge of the hood on one side at least.

In order to make fluoroscopic examinations with satisfaction it is necessary to have the retina in proper condition. If one has been in the bright sunlight it may be necessary to remain in a darkened room for fifteen to twenty minutes before the eyes will be in the best condition for observing the faint illumination of the screen. It is quite likely that for those persons in whom there is lack of color sensitiveness for green the barium fluoroscope will be unsatisfactory. It is probable that the tungstate screen, owing to the color of its fluorescence, will be more satisfactory for persons whose eyes are defective for either the green or the red colors.

Even the light from the tube when it is strongly excited may be sufficient to reduce the sensitiveness of the eye for the picture on the fluorescent screen. As has been mentioned before, this may be prevented by covering the tube with black silk cloth, or by enclosing it in a box.

Fluoroscopic examinations should always be made in a

darkened room. It is convenient to have near the operator's hand a switch for controlling the electric lights of the room, and to have these lights so arranged that they may be run at a very low power for the very slight illumination which is necessary while examinations are being made. Instead of this, a single ruby lamp may be arranged for this purpose.

In order to prevent the light of the tube from disturbing the eyes of the observer, and at the same time prevent the projection of the rays in other directions than are needed, Dr. Williams encloses the tube in a wooden box lined with several layers of white lead paint, and closed in front with a series of diaphragms, which may be adjusted to give different amounts of rays according to the area which it is desired to illuminate. This arrangement is very effective, but it is somewhat clumsy and most operators prefer to use the tube in the ordinary manner.

Adjustable Diaphragms.—Sometimes an adjustable diaphragm is placed in front of the tube to reduce the rays to the area which it is desired to illuminate. Such a diaphragm, made by Siemens & Halske, is readily attached to the tube-holder.

Guarding against Over-exposure.—In making fluoroscopic examinations it will be found that nearly always the patient is subjected to very much longer exposure than is necessary for making several radiographs. Moreover, the observer's eyes are covered with the fluoroscope, and he may move the subject closer and closer to the tube in order to get a better view. Thus the patient is liable to be subjected not only to longer exposures than are safe, but to closer proximity to the tube than is advisable. The risk of injury is therefore much greater than in radiographic exposures. As a matter of fact, most of the severe burns which have led to damage suits have been produced by fluoroscopic examinations. In order to prevent this unpleasant consequence it is well to keep account of the time during which the patient is exposed, and not to allow this to exceed ten or fifteen minutes, with the tube not nearer than 12 or 15 inches from the skin. A screen of thin cardboard or wood may be interposed between the tube and the patient in order to prevent getting too close to the tube while the

observer's eyes are covered by the fluoroscope. The practice of allowing a large number of persons to examine a subject one after another is dangerous unless attention be paid to the matter of time of exposure and distance from the tube.

Screens for Preventing Burns.—It has been alleged that burns may be prevented by interposing between the tube and the patient a thin metallic screen connected by a wire to the earth. Experience has proved that burns may be produced by rays which pass through an aluminum sheet, and that the ground connection is of no value. It can scarcely be doubted, however, that some of the rays which are most easily absorbed, and which are most likely to produce effects upon the skin, will be absorbed by a thin sheet of aluminum; and that the rays which are most useful in making fluoroscopic examinations will be very little obstructed by it. The use of such a screen is, in most cases, an unnecessary precaution, but severe *x*-ray burns are very unpleasant, and it may be well enough to keep on the safe side. Dr. Williams uses for this purpose a thin sheet of aluminum in front of the diaphragm of his box for holding the tubes. It is quite likely that such a screen absorbs more of the low penetration rays, which are more active in causing burns than of the higher penetration rays, which are useful in fluoroscopic examinations.

Importance of Proper Relation of Fluoroscope, Tube, and Patient.—The most satisfactory fluoroscopic pictures will be obtained when the part under examination is brought as close as possible to the fluoroscopic screen in order to reduce the distortion of the shadows to a minimum. It is also important that the rays should fall upon the screen in a direction as nearly as possible at right angles to its plane. Care must be taken, therefore, to keep the fluoroscope directed toward the target of the tube—a matter which is often overlooked. In order to maintain the fluoroscope in proper relation to the tube it is sometimes mounted on an arm which is fixed to the tube-holder, and arranged so as to allow the movement of fluoroscope and tube together.

Fluoroscopic Examinations of Head, Face, and Neck.—In fluoroscopic examinations of the head it will be invariably

necessary to use a tube of high penetration, for the reason that both the skull and the brain offer considerable obstruction to the rays. The thickness of the skull varies greatly in different individuals, and this must be taken into account in interpreting the shadows.

In this region it is well to be especially careful to guard against over-exposure and against getting too close to the tube. Even though no burns occur, it may happen that the hair on one side of the head will fall out. In examining the face and neck the head can be protected by wrapping it with lead-foil about $\frac{1}{50}$ of an inch thick.

Examinations of the face and neck in a direction from side to side will be quite easy. The cervical vertebræ will be dimly outlined, the hyoid bone and cartilages of the larynx will be plainly seen, with sometimes a light streak which marks the course of the trachea. A foreign body, such as a pin or a piece of metal, in the pharynx or upper part of the esophagus may be readily seen. A view from side to side gives us, of course, the antero-posterior relations of the object. In order to determine the position fully it will be necessary to make examinations in the sagittal direction. This is not so easy, for the reason that the lower jaw prevents us from placing the fluoroscope in the best position.

Shoulder.—It is, of course, impossible to obtain a shadow of the shoulder from side to side, but some idea of the antero-posterior relations may be obtained by shifting the patient in a somewhat diagonal position. In most cases it will be found better to make examinations in the sagittal direction, both from back and front of the patient.

Extremities.—Fluoroscopic examinations of the extremities may be made from many points of view. To make such examinations the first step is to place the patient in a position which will be comfortable and which will at the same time allow of the proper disposition of the tube and fluoroscope. This will depend so much upon the nature of the injury that no definite direction can be given here, but suitable positions will readily suggest themselves to any one who is to make such examinations.

Thorax.—One of the most useful fields for fluoroscopic examinations is in examinations of the thorax for lesions of the heart, lungs, and pleural sac. Much may be learned by observing the movements of these parts, the excursions of the diaphragm on either side, the pulsations of the heart, and the pulsations of aneurisms.

Thoracic organs exhibit considerable displacements by gravity in different positions of the body, and examinations of this region will therefore be made with the patient in a sitting or standing posture. For the comfort of the patient it will be well to allow him to sit on a stool or chair with a back of canvas or other material which offers little obstruction to the rays. The distance between the tube and the patient in these examinations will be determined partly by the power of the *x*-rays and partly by the thickness of the subject. In order to avoid undue distortion of the shadow it will be well to have the distance between the tube and the patient not less than two feet. It has been shown by Dr. Cowl that at this distance the amount of distortion is not sufficient to cause serious error.

It is important in making examinations of this region to have a standard position for the tube with reference to the patient. A good position is to place the target of the tube opposite the median line at the level of the fourth dorsal vertebræ. In many cases it will be necessary to examine the patient from other positions than the standard ; for example, the determination of the presence of aneurism of the aorta. The distinctive sign of aneurism is the pulsation, which can almost invariably be observed.

The interpretation of the fluoroscopic pictures of this region is a matter which requires not only thorough knowledge of the pathology of the thoracic organs, but considerable practice in the use of the *x*-rays. Advice and help on these points will be found in the works of Holzknecht, Von Ziemssen and Rieder, Williams, BeClere, and others.

In order to avoid the distortion of the shadow picture in the fluoroscope, and to enable accurate measurements of the size of the heart and other organs which may be traced, Dr.

Moritz has devised an appliance known as the diagraph. In this apparatus a large fluorescent screen, covered with a sheet of celluloid or glass, is held in permanent position in front of the patient. A movable U-shaped arm, one end of which carries the *x*-ray tube and the other carrying a pencil, is arranged so that the pencil may be moved over the area of the screen, and trace an outline on the celluloid or glass. Before using the apparatus the tube and the pencil are adjusted so that a line connecting the tip of the pencil with the source of the

Fig. 57.—Apparatus for orthographic projection of *x*-ray shadows on fluorescent screen.

x-ray passes always through the screen in a direction perpendicular to it. The tube follows the movements of the pencil, and a tracing may be made of the heart or diaphragm, for example, which will therefore be free from distortion.

Dr. Grunmach has designed a modification of this apparatus in which the screen moves with the pencil, and the tracing is made upon a piece of paper which is between the screen and the patient. Several other workers have designed machines of this sort which accomplish practically the same results. Although it has been shown that in measurements of the heart

the distortion is slight when the distance between tube and screen exceeds 2 to 3 feet, it is fair to say that the advantage of securing absolutely orthographic projection upon the screen is well worth considering, and will be of especial advantage with a rather weak exciting apparatus when the tube must be brought close to the patient. A convenient apparatus of this sort, made by the Allgemeine Elektricitäts-Gesellschaft, is shown in figures 57 and 58.

Fig. 58.—Apparatus for orthographic projection of *x*-ray shadows on fluorescent screen.

Abdomen and Pelvis.—Below the diaphragm the fluoroscope is of little use, and is seldom employed except in cases of foreign metallic bodies in the alimentary tract, or bullet wounds, etc.

Location of Foreign Bodies with the Fluoroscope.—The location of foreign substances in the body cannot be accomplished with as much certainty with the fluoroscope as with the radiograph, but on account of the saving of time incident to its use the fluoroscope is often preferable. The common method

of marking the position of a foreign body is to observe it from several different positions, and mark on the skin points corresponding to different diameters passing through the object. In this way location accurate enough for surgical purposes may be made. For convenience in marking the ends of the diameters passing through the object I have used a sort of caliper arrangement, shown in figure 59. The ends of the two arms shown carry metal pieces which when superimposed give the shadow of a cross. The hinge with the handle enables the two points to be separated and adjusted at various distances apart, so that an arm or a leg, for example, may be enclosed between them. They are then moved until the shadow in the fluoroscope shows a cross with the object at the intersection of the two lines of the cross. The two points on the opposite sides of the limb are then marked with a skin pencil, silver nitrate, or iodine. If the pencil is used, it may be necessary to make a scratch on the skin, but marks with iodine or caustic will remain after the skin is cleansed for a surgical operation.

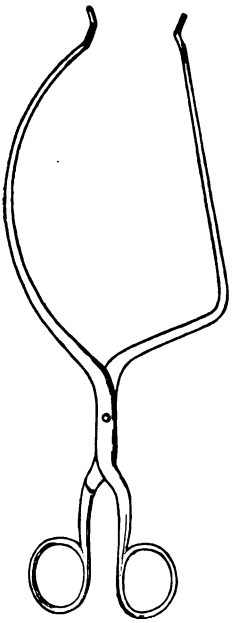


Fig. 59.—Caliper for locating foreign bodies with the fluoroscope. (The straight arm is held against the fluorescent screen.)

Shenton's Method.—When a foreign body can be seen best in only one direction,—as will be the case, for example, with a needle imbedded in the palm of the hand or sole of the foot,—it is not easy to locate it by taking observations in a lateral direction. For such cases as this the method devised by Mr. Shenton, of Guy's Hospital, London, is very convenient. Shenton's description of this method is as follows:

"The surface of the palm of the hand, for example, is held in direct contact with the screen, seeing that the screen and anode in the tube are as nearly parallel as possible. When the needle and bones are seen distinctly, sway the screen and hand

from side to side and note the change in relation of bones and needle. It is evident that the image of whichever is furthest from you and from the surface of the screen will move the faster. If the needle moves across the bones, its position is deeper than the bone; if bones move across the needle, the latter's position must be between the surface of the screen and bone.

"Should the needle appear stationary, place a pointer against this image on the screen and ascertain whether it moved a little or not at all. Verify these results by reversing the hand and repeating the manœuvers. A little practice enables one to give as near an estimate of the needle's real depth as any surgeon could require, and such suggestions as 'just beneath the skin of the palm,' 'lower end between bones,' 'upper end $\frac{1}{8}$ of an inch between the skin of the back of the hand,' are in my experience sufficient for any operator.

"The needle's depth being ascertained, it only remains to find its position in the horizontal planes—a task which presents few difficulties. When found, this position should be marked upon the skin. The advantages of this method are its rapidity of performance, the process taking but a few seconds, and the economy of the material, both photographic and electrical.

"For localization in other parts of the body and for photographically recording results I have constructed an instrument which in principle is the same as the method just described, save that the tube is swayed while the part viewed is held in position by bands and tension springs. The tube is moved by the observer from his side of the screen, the distance it travels being regulated by sliding steps. A fine vertical wire is stretched in the center of, and in contact with, the screen. The image of the foreign body is to correspond with this line when the tube is in the mid-position. Upon moving the tube from the extreme right to the extreme left, the image of the foreign body on the screen is seen to pass from left to right. Its relative rate of traveling compared with the same portion of bone is noted as before.

"For accurate measurements the true position assumed by the foreign body is marked by a pencil on a celluloid film in

contact with the screen. This measurement being secured, the distance the tube travels, and the distance from the mid-point of the line adjoining the two extreme positions of the tube, must be ascertained. A simple rule of three will now give the distance of the object sought from the screen."

Stereo-fluoroscopy.—It was shown by Elihu Thomson in 1896 that two radiographs made by displacing the tube through a distance about equal to that between the eyes, when viewed through a stereoscope, would give the effect of relief. Mackenzie Davidson in 1897 succeeded in obtaining stereoscopic pictures on the fluorescent screen. He has obtained this result in the following way:

He placed two *x*-ray tubes a short distance apart, and excited them alternately by an induction coil. In the field of these *x*-ray tubes he places a stationary fluorescent screen, in front of which are the two sight-holes having a shutter actuated synchronously with the changing of the excitation of the two tubes. He has described two methods of obtaining the alternate excitation of the two tubes. In one of these he uses two induction coils, each connected to one of the tubes, and interrupts the primary circuit of one coil and then of the other. In the other method he uses one induction coil and switches the secondary discharge of the coil from one *x*-ray tube to the other by a revolving switch mechanism. Synchronism between the excitation of the tubes and the operation of the shutter is obtained by attaching the interrupter, the switch mechanism for the tubes, and the shutter to the same shaft, which is revolved by an electric motor. If the distance between the two tubes and their relation to the fluoroscopic screen are properly arranged, a very beautiful stereoscopic effect is produced, and the image seen on the screen, instead of appearing as a flat shadow, stands out in full relief and appears to be really in front of the screen. There is, of course, some distortion of the shadows, and such a stereoscopic picture is, therefore, not absolutely accurate, but it is sufficiently so to be of great practical value.

In December, 1901, the author described in the Electrical Review a modification of this apparatus which resulted in

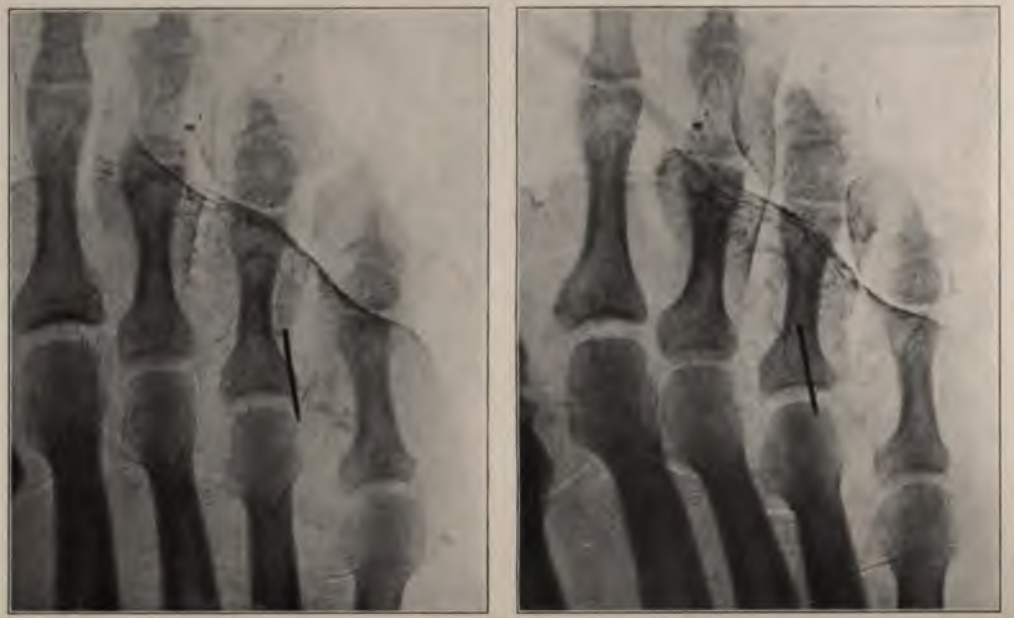


Fig. 60.—Stereoscopic radiograph of a piece of needle in the sole of the foot. The skin of the sole was rubbed with powdered bismuth subnitrate.

somewhat of a gain in simplicity and flexibility. The principle is the same as that of Mackenzie Davidson, namely, that of rapidly alternating pictures and occlusions synchronously of the eyes so that one eye sees always one picture and the other the other picture.

These appliances promise to be of great value in the location of foreign bodies and for fluoroscopic examinations in certain situations where it is difficult to estimate the space relations of the parts in the ordinary fluoroscope. They may also be of great value in enabling the surgeon to replace fragments of broken bones while observing them through the fluoroscope. Up to the present time the mechanical details of these appliances have not been sufficiently perfected to make them available to any but the most painstaking operators.

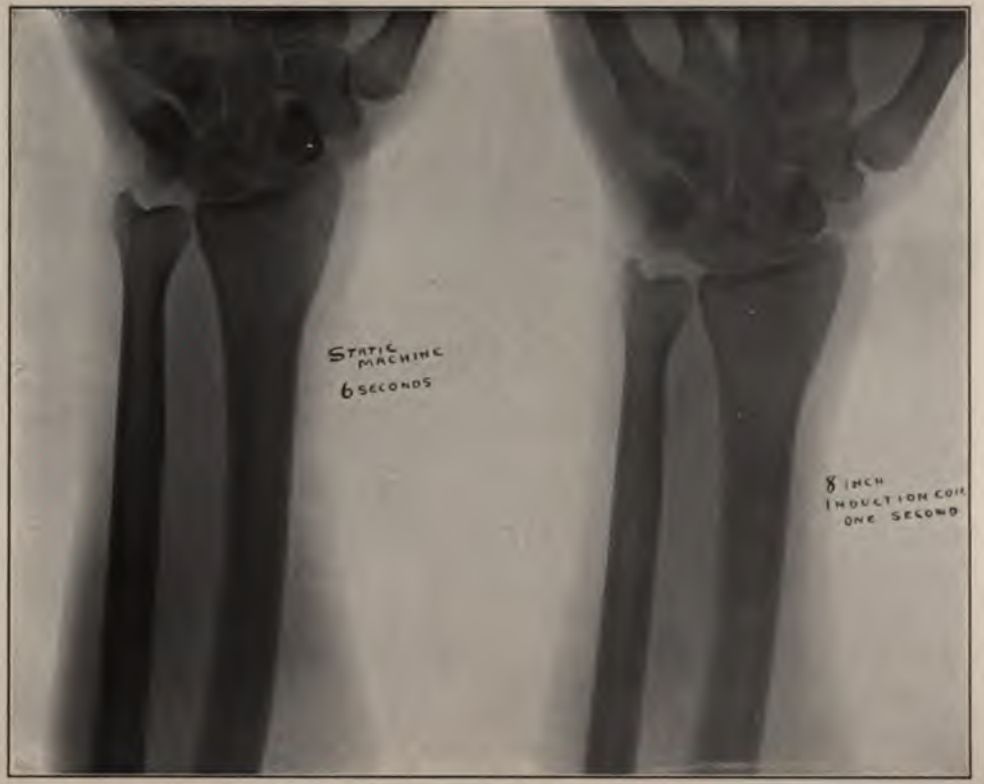
CHAPTER VI.

RADIOGRAPHY.

DIAGNOSIS with the *x*-ray attains its greatest perfection with the radiograph. The beautiful shadow pictures of the fluorescent screen do not approach in accuracy and delicacy of detail those which can be obtained upon the photographic plate. This is a fact that is not generally appreciated by physicians, who often content themselves with a fluoroscopic examination in cases where much more might be shown by a good radiograph. Successful radiographic work requires greater skill in the manipulation of the apparatus than is necessary in any other field in which the *x*-ray is applied. A successful radiographer must have good tubes, efficient apparatus, abundance of auxiliary appliances, considerable skill in the management of the photographic plate, and fair knowledge of anatomy, especially of osteology, together with a good general idea of the common surgical injuries. The art has now progressed far enough so that the best results will not be obtained by a man who simply knows how to operate an *x*-ray machine, and the time has arrived when this work has become a specialty, and should not be entrusted to the hands of hospital orderlies, engineers, and janitors

Success in radiographic work depends much upon three factors: the manipulation of the exciting apparatus, the successful control of the tube, and the proper development of the plate.

Exciting Apparatus.—Exciting apparatus of considerable power is necessary for radiographic work. Either the induction coil or a static machine may be used. The shortest exposures are possible with a coil, but satisfactory radiographs of almost every part of the body may be obtained under favorable conditions with a good static machine. For radiographs of the thicker parts of the body, for examinations for renal calculi, etc., a coil is very much to be preferred. An induction coil



Figs. 61, 62.—Two radiographs of the wrist and a part of the forearm made on the same plate, with the same tube, at the same distance. One half of the plate was covered by a sheet of lead during each exposure. One exposure with 8-inch induction coil and liquid interrupter, one second. One exposure with 24-plate static machine, six seconds. The two radiographs appear to have had about the same exposure to *x*-rays.

not only makes it possible to shorten the exposure, but the quality of ray suitable for this kind of work can be more readily obtained with the coil than with a static machine. In radiographing those parts of the body which are subjected to considerable movement during respiration it is very desirable that the exposure should be made during the time in which the patient may hold his breath. The parts of the body to be considered here are the shoulder, thorax, and abdomen, and these are the parts of the body which are most difficult to radiograph with a static machine.

Duration of Exposure.—It is impossible to state any definite ratio between the time of exposure required for these different types of exciting apparatus, for this will be a matter depending so much upon the condition of the tubes used. A few men have obtained with the static machine excellent radiographs of the extremities with exposures much shorter than those which are ordinarily necessary with an induction coil. However, taking the best exposures that have been made with a coil, and comparing them with the exposures necessary for the same subject with the static machine, the ratio will be between 5 to 1 and 10 to 1 in favor of the coil. Radiographs of the hand, for example, which may be readily obtained with the induction coil in three seconds, will require fifteen to twenty seconds with a very good static machine.

The duration of the exposure in radiographic work depends upon a great many factors: the exciting apparatus used, the efficiency of the tube, the thickness of the part, the sensitiveness of the plate, distance of tube from plate, etc. These factors are so variable that it is impossible to give definite rules for the length of exposures. This is a matter which will have to be determined by each operator by experience gained with his own apparatus. With a favorable subject, apparatus and plates of the best kind, radiographs of any part of the body may be made with exposures of a few seconds. In ordinary practice a majority of workers find it necessary to expose for the hip-joint five to fifteen minutes, for the shoulder five minutes, for the hand one-half to one minute, for the knee and thighs two to three minutes, for the head one to six minutes, for

the elbow and ankle from one to three minutes. These exposures are about the length ordinarily employed with fair apparatus and plates, and without the use of intensifying screens.

Distance of Tube from Plate.—In nearly all radiographic work the distance between the tube and plate * will be not less than 12 nor more than 24 inches from the plate. There will be less distortion of the shadows and less risk of injury to the patient with the tube at a considerable distance, but the effect of the rays on the photographic plate will be reduced almost in proportion to the square of the distance between the target and plate. Therefore in radiographing thin parts of the body, such as the hands and feet, where the distortion will be slight, it is just as well to place the tube as near as 12 to 15 inches. The parts nearest the plate will cast denser shadows than those which are further away, therefore it is advisable always to bring the injury you wish to examine as near as possible to the plate.

In radiographing the joints it is usually desirable to allow the rays to pass between the articular surfaces so that the shadows of the bones entering the injured joint are not superimposed.

Clothing.—It is true that the clothing offers very little obstruction to the *x*-ray, but for several reasons it is advisable to have the parts to be radiographed uncovered, or at most covered only by a single layer of cloth. Unless this is done it is difficult or impossible to properly place the tube and plate with reference to the subject. Seams of clothing and buttons cast shadows which may impair the usefulness of the radiograph. Especially is this so if we are trying to locate a stone in the kidney or a foreign body in the intestine.

Radiographing Both Sides for Comparison.—In injuries of the hands or feet and other parts of the body it is often desirable to show on the same plate a radiograph of the normal part on the other side of the body. This is especially useful if the radiograph is to be used as evidence in court.

* In recording the position of the tube it is convenient to state the distance between the target and the plate. This method is used where the distance of the tube is mentioned in these pages.

Bandages, Splints, Plaster Casts, etc.—It is, of course, unwise to remove bandages and splints for the purpose of making radiographs in cases of recent fractures, but it will be a great help to the radiographer if the dressings are of a material which is not opaque to the ray, and if in bandaging a limb proper regard is had to the position which will be used in making radiographs. Surgeon's plaster ordinarily contains soaps of lead or zinc, and these materials cast shadows. Iodoform dressings also cast more or less dense shadows. Rubber drainage-tubes show in the radiograph, but they need not be mistaken for anything else. The ordinary wood splints used in cases of fractures offer no serious obstruction to the *x*-rays, and in these cases the usual difficulty is that the limb is so bandaged it is impossible to place the plate in proper relation to it. Radiographs through plaster casts show enough to indicate whether the fragments of a fracture are in proper relation or not. Longer exposures will be required with plaster casts, and the radiographs will always be hazy and mottled by the shadows of the plaster. The starch dressings which may sometimes be used instead of plaster-of-Paris offer very little obstruction to the rays.

Diagnosis of Malignant Growths.—It is rarely, if ever, possible to show with the *x*-ray malignant growths of the soft parts of the body which are not readily recognizable by other means. For malignant growths of the bone, and foci of necrosis in them, the *x*-ray is a very valuable aid in diagnosis, but in the soft parts it is of little use.

Marking the Skin.—In the location of needles and pieces of metal near the surface of the body it is often desirable to show the skin in order to assist in estimating the depth of the object. This may be accomplished by smearing the skin with oil, and then rubbing it with powdered bismuth subnitrate. The rugæ on the skin of the palm of the hand and sole of the foot may be beautifully shown by this method. Figure 60 shows a stereoscopic radiograph of a needle in the foot with the skin of the sole treated in this way.

Tubes for Radiographic Work.—For the most rapid exposures with powerful induction coils it will be necessary to use strong,

heavy tubes with targets of thick metal, or those with water-cooling devices. These tubes are very expensive, and when used under the conditions mentioned above will have a very short life. The cost of tubes will be less if weaker exciting currents are employed, and the exposures somewhat prolonged. If this is done, cheaper tubes may be employed and they will have a longer life. When fairly long exposures are to be made, it is better to use tubes which have targets made entirely of platinum. With the most powerful static machines that are made it will be possible to use tubes which are not heavy enough for use with a fair-sized induction coil.

Definition.—It has already been mentioned that in order to secure sharp shadows there must be a single source of the *x*-ray from an exceedingly small point. Even in a tube which is well focused there may be comparatively weak sources of *x*-ray at points on the bulb, and other places than the target, which will tend to impair the sharpness of the shadows.

Secondary Rays.—Röntgen has shown that secondary rays capable of affecting a photographic plate are produced when the *x*-rays pass through air or through any other material. Obviously these secondary rays, although very weak, will sometimes be strong enough to have an undesirable effect upon the plate.

The use of metal diaphragms and the placing of the tube in an opaque box for the purpose of obtaining sharper shadows has already been mentioned. For lessening the effect of these secondary rays some operators use a metallic funnel between the tube and the subject; the small end of the funnel, being opposite the tube, acts as a diaphragm. Its walls protect the plate from the secondary rays arising from surrounding objects. To protect the plate from the secondary rays which may reach it from below it has been suggested to use a sheet of metal at the back of the plate.

Most of these devices are somewhat clumsy, and it is doubtful whether they are of sufficient advantage to offset the inconvenience of employing them.

Degree of Penetration.—Rays of low penetration have the greatest effect upon the photographic plate, and for making

radiographs therefore it is advisable to employ a tube of much lower penetration than would be desirable for fluoroscopic examinations. The degree of penetration necessary will be determined somewhat by the thickness of the part which is to be radiographed, and also by the structures which we wish to show. When it is desired to show the bones of the extremities with as much contrast as possible, and to produce a radiograph which shows little or nothing of the soft parts, a tube of quite low penetration should be used, and the exposure should be fairly long. With a tube of high penetration there will be less contrast between the bones and flesh, and it will be found impossible to develop the plate so as to blot out the flesh without also obscuring the bones. Such a tube should be used when it is desired to show the soft parts of the body. The exposure should be short, and the development carried out without any regard to the bones.

For showing the bones of the hand, arms, feet, and legs a tube having a resistance equal to an air gap of 1½ to 2½ inches will usually give the best results. For the thicker parts of the body, such as the pelvis, head, and shoulder, it will be necessary to employ a tube of little higher penetration. Most tubes operate satisfactorily for this work when the resistance is equal to an air gap of about 3 or 3½ inches. For the thorax a somewhat lower penetration is required than for the parts below the diaphragm.

When it is desired to show the softer parts, tubes of a resistance equal to an air gap of 5 or 6 inches may be used, but when such tubes are used care must be taken to guard against the disturbing effects of the secondary rays. These effects will be reduced by enclosing the tube in a box lined with white lead or by the use of diaphragms, etc.

Tube-holders.—The supporting device for the tube should be firm and steady in order to prevent blurring of the radiograph by movements of the source of *x*-ray during exposure. It should be strongly made and stiff so that it will not vibrate, and it should have three legs, not four, so that it will stand firmly upon an uneven floor. Most of the tube-holders on the market are far too slender and lightly constructed, and are therefore unsteady.

It will be necessary to support the tube in a great variety of positions, and the tube-holder should therefore allow of a wide range of adjustment in position.

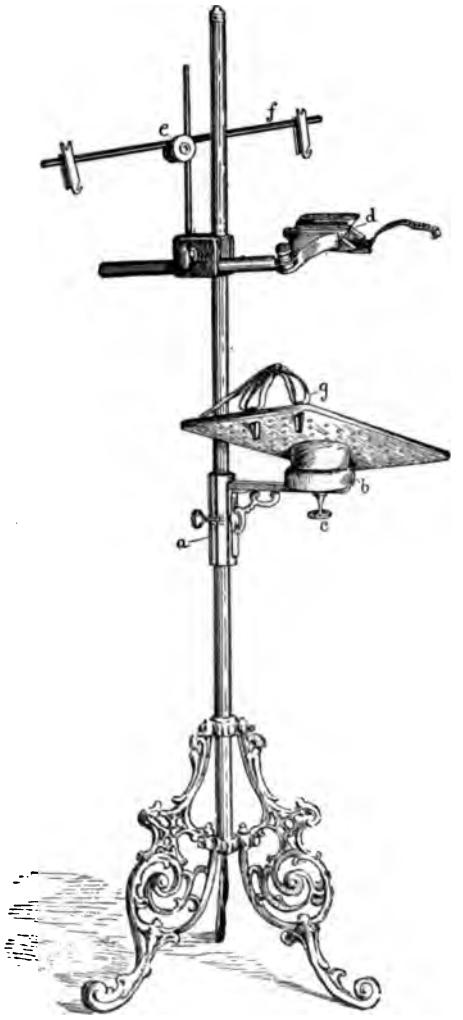


Fig. 63.—Tube-holder with adjustable shelf for supporting photographic plate and subject to be radiographed (E. W. Caldwell): *a*, Clamp for holding shelf to vertical rod (shelf may be removed); *b*, ball-joint which allows shelf to be tilted 30 degrees from horizontal plane; *c*, hand-wheel by which shelf is clamped in position; *d*, tube clamp with perforated strap; *e*, universal clamp for wire spreader; *f*, wire spreader with adjustable hooks for wires; *g*, strap and fasteners which may be attached to any part of the shelf for holding subject in position.

There are a number of tube-holders with which the tube can be held in proper place for radiographing the foot upon the floor, or a hand upon the table, or for fluoroscopic examinations of the head and neck of a tall man. I have used at the Edward N. Gibbs *X*-ray Laboratory for some time the tube-holder shown in figure 63. This tube-holder consists of an upright rod of $1\frac{1}{4}$-inch brass tubing which is supported by a base of cast metal having three legs, thus giving steady support. The arm carrying the tube is adjustable in the amount of its projection beyond the vertical support, and may be rotated upon its axis. The tube is held between two V-shaped projections of wood by means of a strap which is attached at one end

to a piece of elastic webbing. The other end is perforated with a number of holes to fit over a projecting pin. With this device an even tension may be put upon tubes of any size without any fear of straining the glass, or having them held so loosely that they will drop out. The tube clamp is arranged on a curved piece of wood which brings the target of the tube opposite the axis of the horizontal rod, and rotation of the plane of the target may therefore be made without materially changing its position. The joint of the tube clamp with the horizontal rod enables a certain amount of rotation of the tube on a vertical axis, which is often desirable in order to keep the lead wires at a safe distance from the patient.

Fig. 64.—Tube-holder and support for photographic plates.

For supporting the hand, elbow, foot, knee, etc., during radiographic exposure a wooden shelf is arranged to be clamped to the upright rod of this tube-holder, and adjusted by changing the height as may be convenient. The shelf is attached to the clamp by a special ball-and-socket joint which allows it to be tilted in any direction through an angle of 30 degrees for the purpose of properly adjusting the plane of the plate with reference to the part to be radiographed. It is also perforated with a number of holes $\frac{3}{8}$ of an inch in diameter, and spaced about one inch apart. These holes are for the purpose of attaching straps and other appliances to the shelf for firmly supporting the part, and preventing movement during exposure.

An excellent device of German make for supporting tubes and plates in radiographing various parts of the body is shown in figures 64, 65, and 66. This has a small shelf or table adjustable on a ball-and-socket joint, and also adjustable in its height. The shelf carries the tube-holder, the details of which

are shown fairly well in the drawing. This appliance has the advantage that the adjustment of the tube is not made independently of the adjustment of the shelf; that is to say, the tube may be adjusted with proper relation to the plate and then the plate and the tube-holder adjusted in proper position to the patient, thus effecting more or less saving of time. Personally I prefer the form shown in figure 63, for the reason that the shelf can be removed, and it is therefore better adapted for use over a table. There are other tube-

Fig. 65.—Tube-holder and support for photographic plates.

Fig. 66.—Tube-holder and support for photographic plates.

holders in the market which answer the purpose very well. Any tube-holder which has a good firm support, which holds the tube firmly and without vibration, and which admits of considerable range of adjustment, will be satisfactory.

Tables.—For many radiographic exposures it is convenient to have the patient in a recumbent position upon some kind of couch or table. The requirements of the various cases to be radiographed are so diverse that it is almost impossible to get a table which will be convenient for every sort of a

case. The comfort of the patient suffering from an injury which is to be radiographed is a matter which is often difficult to provide for, and still obtain a position which is best to secure the desired relation of the photographic plate and tube. Probably nothing has been made which will give more satisfactory results than a good gynecological chair or table. These chairs have been made the subject of long and careful study, and some of them give a great variety of adjustments. In selecting

Fig. 67.—Fiber-top table for radiographic work.

a chair for this purpose it will be an advantage to procure one which may be rotated upon a vertical axis, and it is very desirable that the arm-rests should be of the style that may be removed, so that when the chair is in a horizontal position they do not project above the cushions upon which the plate-holder will rest.

One disadvantage of the gynecological chair is that neither the tube nor the plate can be placed underneath it, because

the materials of which it is made will cast shadows. For work of this kind some operators employ a canvas stretcher supported on wooden horses. The canvas offers, of course, no appreciable obstruction to the rays, and therefore allows the tube to be placed underneath the patient and the fluoroscope or photographic plate above. The stretcher is also of advantage as a means of transporting the patient. It also has the advantage that the plate may be supported underneath the stretcher, and the patient will then be saved the discomfort of lying upon its hard surface. A canvas-topped table possesses also the same advantages. The patient may be placed upon such

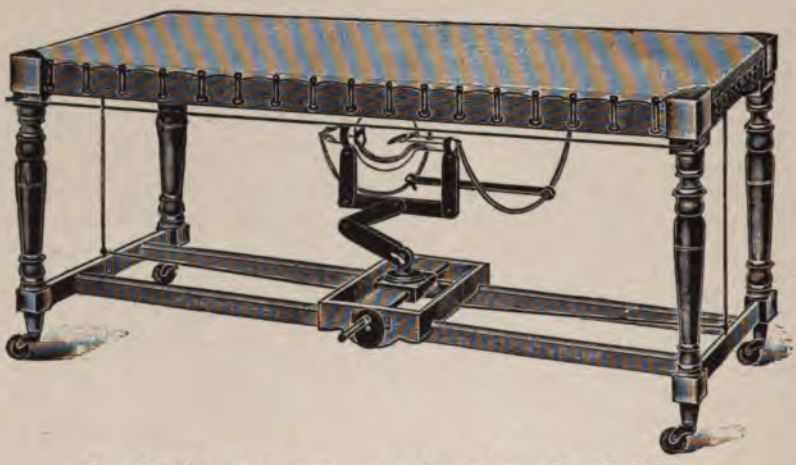


Fig. 68.—Shenton's canvas-top table with movable tube-holder.

a table and radiographed without removing him from the stretcher.

A number of makers supply tables with tops made of thin fiber or other material which offers very little obstruction to the *x*-ray and which is firmer and stiffer than canvas. These table tops are usually made in two parts, hinged so that the end supporting the head may be raised and held at a considerable angle with the horizontal part of the table. A table of this type which is made by Queen, Willyoung, and others is shown in figure 67. Some of these tables are provided with special devices for supporting the plate in various positions

underneath the table top. The canvas-topped table made by Dean, of London, from a design of Mr. Shenton's, is provided with a tube-holder which may be adjusted in various positions underneath the table top, for use with the fluorescent screen or photographic plate placed over the patient. (See Fig. 68.)

Envelopes and Plate-holders.—There are many devices in use for guarding the plate against ordinary light while the radiographic exposure is being made. The simplest of these consists of a pair of paper envelopes, a little larger than the plate: one of black paper and the other of orange paper. These may usually be obtained from the dealer in photographic materials, and they are usually supplied with *x*-ray plates. Some makers furnish the plates ready for use in the envelopes. This practice is objected to on the ground that chemical substances in the paper gradually cause deterioration of the sensitive film of the plate if left in contact with it for some time. This objection is undoubtedly a valid one, although with some papers the effect is very slight indeed. I have obtained excellent results with plates that have been in the envelopes for two months or more. It is safer, however, to buy the plates packed in the boxes in the usual way and to put them in envelopes or plate-holders not very long before they are to be used. Ordinarily the plate is placed first in the black envelope, and then this black envelope is placed in the yellow envelope, keeping the film side of the plate always nearest the plain side of the envelopes. This, of course, must be done in the dark room. In practice I try to keep constantly on hand in the envelopes enough plates for two or three days' use, and to use them rapidly enough so that they do not remain in the envelopes longer than a week.

Fig. 69.—Plate-holder for radiographic work.

Several makers of *x*-ray apparatus furnish wooden-backed plate-holders for use instead of the paper envelopes. A holder of this sort, which is used by many German workers, is shown in figure 69. These plate-holders are good, and they have the advantage of protecting the plate against breakage by the weight of heavy subjects placed upon them, but they are very bulky, and then sometimes the thickness of the wooden backing is objectionable. I prefer to use in most of my work the primi-

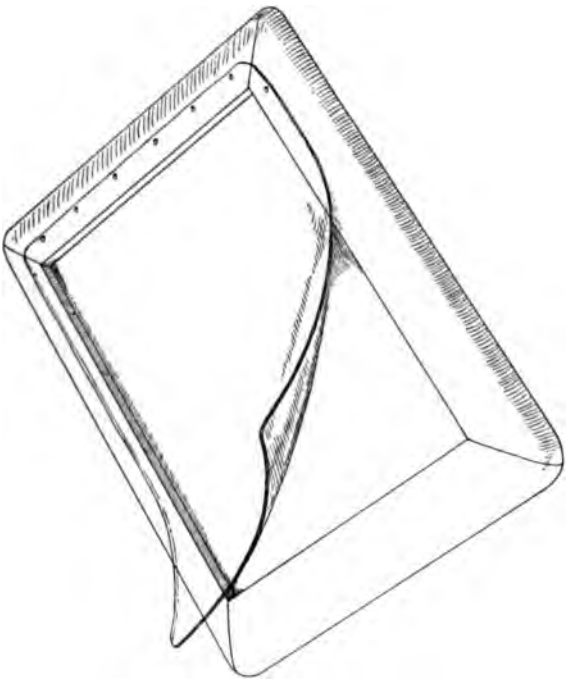


Fig. 70.—Plate-holder for plates enclosed in paper envelopes.

tive paper envelopes. For use with intensifying screens, however, a plate-holder is more convenient, and for this purpose special plate-holders have been designed.

When the photographic plate is placed underneath the part to be radiographed on a cushioned chair or table, it may be necessary to provide it with a stiff backing in order to prevent it from being broken by the weight of the subject. For this

purpose I have designed a holder shown in figure 70 which is intended to be used with plates wrapped in ordinary paper envelopes. It will be seen that this plate-holder consists of a board having a recess to receive the plate, and its edges rounded and beveled in order to produce as little discomfort as possible in contact with the body. It is covered with a thin sheet of celluloid, which is attached at one edge, and may be lifted up for inserting the plate. The object of celluloid is to protect the plate against perspiration or other excreta from the body. When no plate-holder is used, it is convenient to have sheets of thin celluloid cut to the size of the envelope holding the plate, to be placed between it and the patient, for the same purpose.

Some workers consider it essential to place in the plate-holder and underneath the plate a sheet of metal in order to protect against the action of the secondary rays. This is not a bad idea, although if exposures are short it is quite unnecessary. A convenient backing may be made of a sheet of heavy lead-foil about $\frac{1}{50}$ of an inch thick, cut to the size of the plate.

Intensifying Screens.—A very considerable reduction in the time of exposure may be effected by placing in contact with the photographic plate a screen of material which fluoresces strongly with an actinic color. For this purpose it is customary to employ fluorescent screens made of thin flexible celluloid coated with calcium tungstate, which fluoresces with a bluish-white light.

In using such a screen the side coated with the crystals is always placed in contact with the emulsion of the plate or film. The object to be radiographed may be placed either at the back of the plate or at the back of the screen. In the one case the rays pass directly through the screen, and therefore if there are uneven spots in it they will cast shadows upon the plate. In the other case the rays pass through the glass before they reach the emulsion. The glass of the plate is rather more opaque than the screen, and therefore reduces to a greater extent the intensity of the rays falling upon the emulsion. Celluloid films, however, offer practically no ob-

struction to the rays, and may be used in this manner with considerable advantage.

In much of the fastest work that has been done in Germany films doubly coated on each side are placed between two such tungstate screens, thus utilizing to the greatest extent the advantages of the fluorescent screen, and the multiple coatings of the emulsion. The ratio of the exposure necessary with a single intensifying screen and photographic plate to that which is necessary with the same plate without the screen is about 1 to 4 or 5. With a double film and two screens the exposure may be reduced to perhaps one-tenth of what is necessary under ordinary circumstances. Thus it can be seen that the use of a screen offers a very decided gain in the time of exposure. It must be remembered, however, that there is marked impairment of the character of the picture, due first to the shadow of the crystals, and, secondly, to the fact that the screens as they are made do not fluoresce uniformly, and do not lie flat over the surface. Hence there is mottling of the negative even with the plate between the screen and the tube.

It must be borne in mind that these intensifying screens phosphoresce for some time after the *x*-ray exposure has ceased, and therefore it is important to keep the screen in exactly the same position in reference to the plate after the exposure is made. If the screen is placed in an envelope, it is likely to slip more or less away from its first position in handling the plate after the exposure is made. When this occurs, the phosphorescence, which persists for some time afterward, may cause the picture to become blurred.

Prevention of Movement during Exposure.—With the most powerful *x*-rays we are able to produce, the action on the photographic plate is very much less intense than that of ordinary light, and radiographic exposures are very much longer than those ordinarily employed in camera work. This is often a serious disadvantage because of the liability of the subject to move during an exposure. The movements may be involuntary, as the respiratory movements, or nervous twitchings, which seem very liable to occur in the neighborhood of the machine. It is often very

difficult to keep young children quiet long enough to obtain a satisfactory radiograph.

It is therefore necessary to take every precaution to guard against movements of the subject and consequent blurring of the picture. To accomplish this end it will, of course, be advisable to place the patient in the position which is as nearly comfortable as possible. In order that he may not be startled when the exposure begins, it is a good idea to have a short rehearsal without the photographic plate, so that he may become accustomed to the noise and the appearance of the tube.

The use of straps for holding the part in position has already been mentioned. For the same purpose it is very convenient to have a number of canvas bags partially filled with sand. These may be placed on top of the subject, beyond the limits of the plate, and often assist in maintaining a fixed position.

With a healthy adult the movements of respiration may be stopped long enough to obtain a radiograph of any part of the body with the most powerful apparatus. In order to make it easy for the patient to hold his breath, he may breathe rapidly and deeply for a minute or two before the exposure is made. This in some way produces a condition of apnœa, and respiration may be suspended without discomfort for thirty to one hundred seconds, which under proper conditions is long enough to make a radiograph of any part of the body.

The majority of operators, however, will probably not succeed in obtaining such short exposures as this. In order to obtain sharp shadows with longer exposures Dr. Cowl has devised a method of making a radiograph while the patient is breathing, but exposing the plate only during the pause at the end of each expiration. If it is desired, the same arrangement may be used to expose for a very short time at any period of the respiratory movement, and thus show the parts as though they were fixed in position.

In Cowl's apparatus the induction coil circuit is opened and closed by a relay, the circuit of which is in turn opened and closed by a contact device clamped against the thoracic wall in such a position that the contact is closed and opened

at any desired point of the respiratory movement. The same result may be obtained more or less imperfectly by opening and closing the induction coil switch by hand in synchronism with the movements of the thoracic wall.

Importance of Correct Pose.—When we consider that radiographs are all shadow pictures, it will be obvious that it is of the greatest importance to place the subject, the tube, and the plate in such relation that the shadow will give us the information we desire. Even with a fair knowledge of osteology it is more or less difficult to know what kind of a shadow the bones will cast with the source of light in various positions. A very slight change in the position of the source of the *x*-ray will often make a great difference in the shadows on the photographic plate. In order to assist in determining the best position of the tube for making an exposure, and also for correctly interpreting the radiograph after it is made, I have found it very helpful to study the shadows produced by an articulated skeleton with a small point of light, such as may be obtained from a one candle-power incandescent lamp held in the position of the *x*-ray tube.

Examining the Negative.—It is often difficult to obtain a really good print from an *x*-ray negative, and it is therefore advisable to learn to examine the negative, and not rely upon the print. After one has become accustomed to looking at negatives they will be much more satisfactory than the best print that can possibly be made.

Illuminating Device.—In order to examine the negative to the best advantage it should be viewed by transmitted light only; that is, it should be examined in a room which is darkened, and into which light is admitted through the negative. Usually one may see more in a negative by holding it up before a gas flame or an electric light than in front of a window. The best method is to use a special illuminating device which throws a very strong light through the negative and cuts off all that does not pass through it. An apparatus which I have devised for the Edward N. Gibbs *X*-ray Laboratory is shown in figure 71. Several incandescent lamps are arranged in a box having a white asbestos lining. The box is covered by a sheet of

ground glass, and at a distance of an inch from the ground

Fig. 71.—Illuminating device for examining negatives.

glass is a second plate of plain glass. At the sides of the box are four shades of material opaque to light, and which are

held by four spring shade rollers. These shades are arranged so that they overlap, and by adjusting them at various points any rectangular area up to the full size of the box may be illuminated. The negative resting on the plain glass may be enclosed by the shades in such a way that no light from the lamps can be seen except that which passes through it. One advantage of this shade roller arrangement over other devices which have frames to fit different sized plates is that it enables one to occlude the light from any part of the plate under examination and allow it to pass only through the part which one wishes to examine. At the side of the box is a small rheostat which acts as dimmer for regulating the intensity of the light according to the density of the negative to be examined. This dimmer has the disadvantage of changing the color of the light at the same time that its intensity is varied. The intensity of the light may be changed without changing its color by using long cylindrical incandescent lamp bulbs, then sliding over them to a greater or less extent sleeves of an opaque material which occlude more or less of the filaments.

In examining a very thin negative it will sometimes be found an advantage to get away three or four feet and view it from a direction of 45 degrees or less from the plane of the plate.

Marking the Negatives.—In order to identify negatives and enable them to be conveniently found for reference it will be necessary to number the negatives and to keep a more or less elaborate system for recording and filing them. A large collection of negatives arranged for convenient reference will often materially assist in the proper interpretation of radiographs and in determining the best conditions for making a radiograph of a given subject. It is therefore desirable to mark the negatives in some way, and to have some good expansible system for recording and filing them.

Negatives may be marked in several ways, and perhaps the simplest is to mark on the film with an ordinary lead-pencil in the dark room, just before the exposure is made, the number, name of patient, position, the time of exposure, or any other information which may be desirable. These pencil marks will remain after development, and may be read without much diffi-

culty. However, it is not convenient to prepare each plate in the dark room just before its exposure, and it will be easier to mark the plates in some way which does not require opening the envelope or plate-holder. This can be done by placing over the plate, while the exposure is being made, letters or figures made of metal. Small lead letters and figures such as are used by pattern-makers and are sold as "pattern letters" are very convenient for this purpose. An arrangement which I have devised for supporting these letters and figures is shown

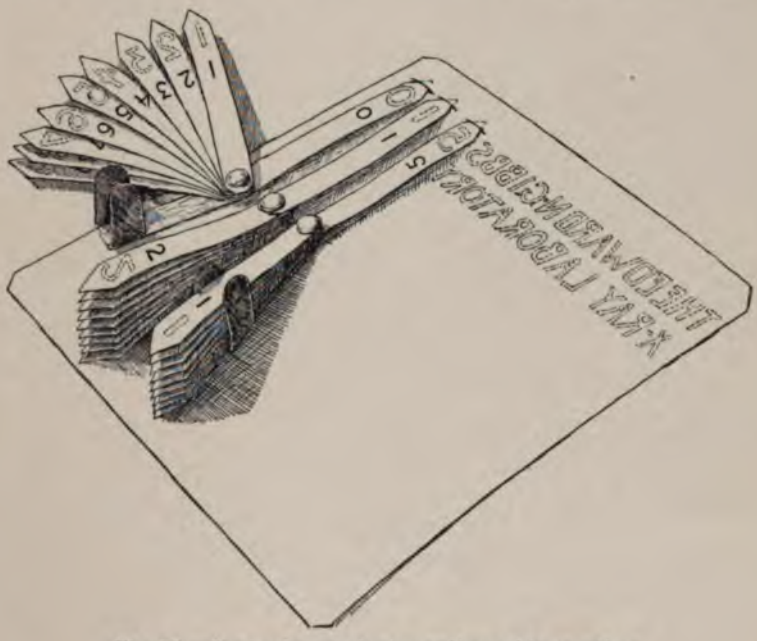


Fig. 72.—Device for numbering radiographic negatives.

in figure 72. In this device three sets of figures from 0 to 9 are fastened to little strips of celluloid, and arranged so that any number from 0 to 999 may be selected and placed over the plate. These numbers are fastened to the under surface of the celluloid by little strips of surgeon's plaster. It will be noticed that they are arranged so that in the negative when it is viewed from the back, and also in the print, the letters will read from left to right. The appearance of a print from

a negative marked in this way is shown in figure 73. In addition to the operator's initials, it will often be convenient to mark the negative with the letters R., L., A., P., I., or E., indicating the right or left side of the body, and whether anterior or posterior, internal or external, side of the subject is placed nearest the plate. In many cases the position will be such that these letters will be unnecessary, but they are often found convenient.

I find it convenient to number the negatives consecutively regardless of size, and to record them in numerical order in a book, adding after each number in the book the letter A, B, C, D, to denote the size of the plate. Plates of the same size will naturally be filed together, and this letter enables one to tell in what part of the filing case the plate will be kept. It will not be necessary to use more than three to five sizes of plates at the very most, hence filing of plates of the same size together will not complicate the system much.

Record Book.—A sample page of the record book used at the Edward N. Gibbs *X*-ray Laboratory is shown in figure 75. This book was arranged to enable a fairly detailed record to be kept with as little writing as possible. It will be noticed that there are different columns for different parts of the body, and the letters in the columns indicate whether the right or left side is shown, whether anterior or posterior, internal or external, side was placed nearest the plate in making the radiograph. This arrangement in columns not only saves writing the name of the part exposed, but enables one to readily select from the book the numbers of all negatives of any particular part of the body. In the record of the *x*-ray exposures the vacuum of the tube is registered by the length of the spark gap, the distance from the target to the plate is registered in inches, and the time of exposure in seconds or minutes. This record book enables one to ascertain most of the data about any plate when its number is known, but does not enable one readily to find a given negative when only the name of the patient is known. Therefore it is supplemented by a card-index in which the numbers of the plates of each patient are registered on a card. These cards are, of course, filed alpha-

Fig. 73.—Radiograph of a normal elbow-joint. Hammer Aurora plate, glycin developer. Heavy target tube, target 15 inches from plate. Induction coil (8-inch spark length), liquid interrupter. Exposure one second.

betically according to the patient's name. The size of these cards will depend upon how much of the history it may be desired to record. The patients at the Edward N. Gibbs *X*-ray Laboratory are all cases whose histories have been recorded in

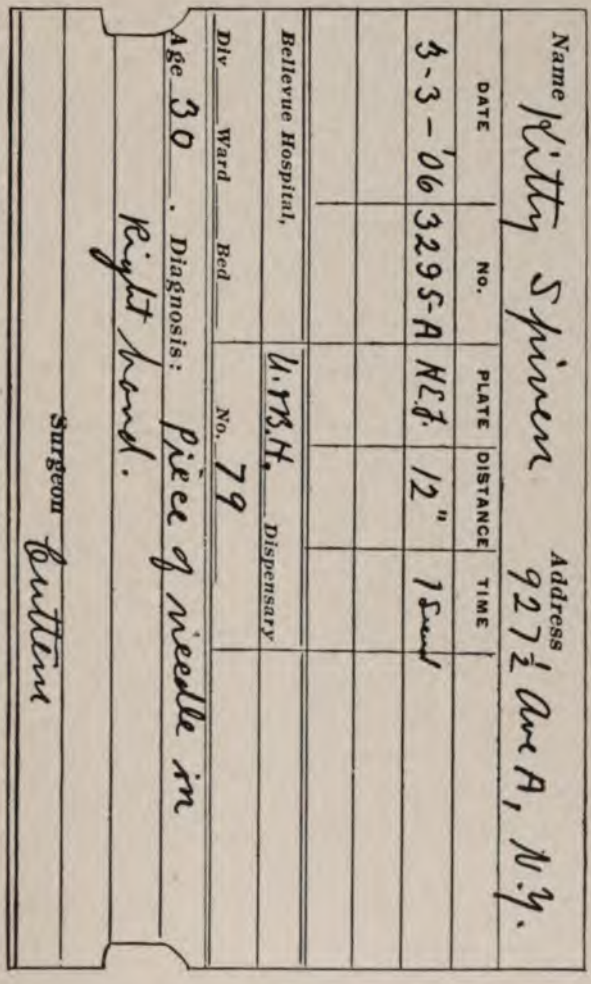


Fig. 74.—Card from card-index of the Edward N. Gibbs *X*-ray Laboratory.

the college dispensary or hospital records. Hence it is only necessary here to refer to the hospital or dispensary number to enable the clinical data to be traced. A sample of this card is shown in figure 74.

THE EDWARD N. GIBBS X-RAY LABORATORY

Case Number	Date	Name of Patient	Head	Neck	Thorax	Shoulder	Upper Arm	Elbow	Fore Arm	Wrist and Hand	Abdomen	Pelvis and Hip Joint	Thigh	Knee	Leg	Ankle	Foot
3290 D	2-29	Won Lung 44½ Pell St. N.Y.			P												
3291 B	2-29	J. Cummon Hackensack, N.J.												R P			
3292 B	2-29	" "												R E			
3293 D	2-29	George W. Snobal 901 Thompson St. N.Y.									P						
3294 D	3-3	" "									P						
3295 A	3-3	Kitty Spinen 927½ Ave A, N.Y.								R P.							
3296 C	3-4	Terrence Dooley 806 E. 18 St. N.Y.														R E	R E.
3297 B	3-4	L. Imburgher 891 E. 72nd St. N.Y.				R P											
3298																	
3299																	

Fig. 75.—Page from record book of the

UNIVERSITY AND BELLEVUE HOSPITAL MEDICAL COLLEGE

Renal, Vesical and Biliary Calculi	Bullets and Foreign Bodies	Fracture	Dislocation	Exostosis	Neurosis	Tuberculosis	Malignant Growth	Remarks	SURGEON	Plate	Tube	Vacuum	Distance	Time	
						X		T. B. C. cont. in Lept. Lung	Dr. Killeen	11 x 14	16	2½"	20"	8s	8" induction Coil.
			X						"	10	14	3	15	5s	"
			X						"	"	"	"	18	7s	"
	X							Bullet wound	Dr. Cuttem	"	24	3	18	20s	"
	X							"	"	"	"	"	"	"	"
	X							Needle in hand	"	10 x 12	12	2½	12	1s	"
								Flat foot	Dr. Yellow	"	14	3	16	15s	"
		X						Fracture surgical shock	"	"	"	"	18	4s	"

Edward N. Gibbs X-ray Laboratory.

Preserving the Negatives.—It is well to protect the negatives in ordinary manila paper envelopes which are made for that purpose and sold as "negative preservers" at all photographic supply houses. Negatives may then be filed in cases such as are shown in figure 76. As will be seen, these cases are divided by vertical partitions into compartments about two inches wide which will hold conveniently about a dozen negatives. The envelopes are, of course, numbered in the

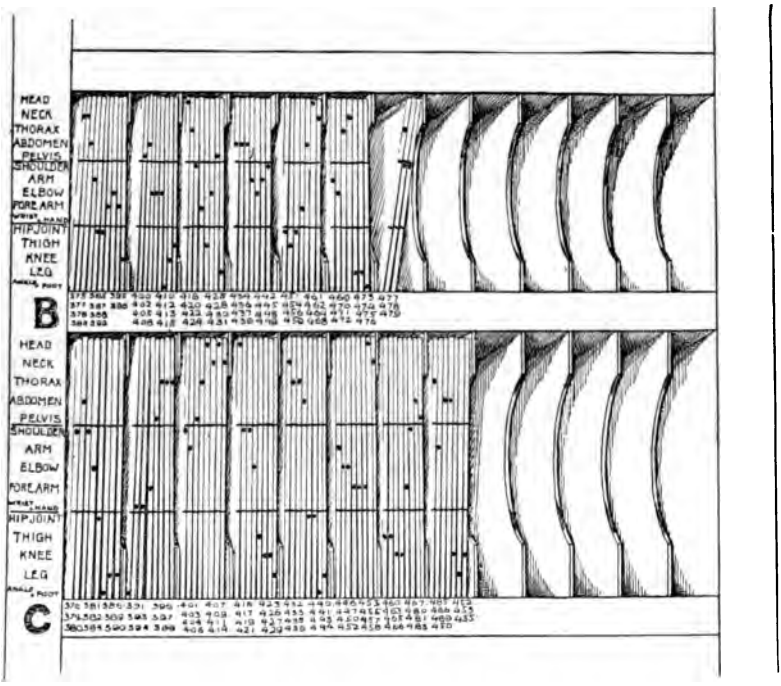


Fig. 76.—Filing case for negatives, showing indicators for radiographs of different parts of the body.

corner to facilitate finding any plate, and these numbers are also marked on a card at the base of the compartment.

A large collection of negatives which are so carefully filed and indexed that radiographs of any particular part of the body may be readily selected from the case for comparison will often prove very valuable and aid in the correct interpretation of other radiographs, and in determining what sort

of an exposure may be best for obtaining a given result. To assist in selecting from the filing case negatives showing any part of the body I have devised a marking system for the envelopes which is visible from the edge, and which indicates at a glance whether the negative contained in it shows a head, shoulder, foot, arm, etc. The front edge of each envelope is divided by two horizontal lines into three equal spaces, each one-third of the length of the envelope. The envelopes are prepared with these horizontal lines. The indicator consists of a little piece of gummed colored paper which may be pasted on the edge of the envelope, and which by its position indicates the part of the body shown in the negative. If the negative shows the head, neck, thorax, abdomen, or pelvis, the paster is placed in the upper one of the three spaces, and its position from top to bottom of the space indicates which of these five parts are shown. In a like manner the five divisions of the upper extremity—that is, shoulder, humerus, elbow, forearm, wrist and hand—are indicated by the position of the paster in the middle space. In the same way the divisions of the lower extremities—that is, hip-joint, thigh, knee, leg, ankle and foot—are shown by the different positions of the paster in the lower division of the envelope. Obviously an envelope with the paster at the bottom of the lower division contains a negative of the foot. A radiograph of the head will be marked by the paster at the top of the upper division, a radiograph of the elbow will be marked by a paster at the middle of the middle division, etc. This filing system is, of course, more elaborate than will ordinarily be needed. However, there are men who have cases under observation for years, and often find it advisable to refer to radiographs made a long time previously, and for these the value of such a system will be apparent.

Upper Extremity.—Radiographs of the upper extremity will naturally fall into the five divisions mentioned above; that is, shoulder, arm, elbow, forearm, wrist and hand. All of these parts in the normal subject are comparatively easy to radiograph; and in cases of injury to these parts the only difficulty is that of securing proper relation of plate, tube, and subject without discomfort to the patient.

The wrist and hand are perhaps the easiest parts of the body to radiograph. There are ordinarily two positions in which these parts are shown—that is, from front to back and from side to side.

For the antero-posterior view by far the most convenient arrangement will be to rest the hand with the palmar surface upon the plate, and place the tube over it at a distance of 12 to 18 inches; the only special precaution necessary is to have the forearm well supported so that no movement occurs during exposure. Any table will answer perfectly well for this, but it is convenient to have it adjustable to suit the height of the patient. The tube-holder shown in figure 63 with the adjustable shelf is very convenient for this purpose.

For a side to side view of the wrist and hand it is only necessary to rotate the hand through an arc of 90 degrees, and this will be readily accomplished by supination of the forearm. The method of radiographing the middle of the forearm does not differ essentially from that for the wrist.

Elbow.—For radiographing the upper part of the forearm, the elbow-joint, and lower part of the humerus the same tube-holder and shelf will be found of the greatest convenience. It will be usually desirable to make two radiographs of this part—antero-posterior and lateral.

Injuries of the elbow-joint are often accompanied by anchylosis and some deformity which makes it difficult to secure proper relations of the tube, arm, and plate, and it therefore becomes almost a necessity to use some special form of supporting device, such as the ones shown in figures 63 and 64.

In making an antero-posterior view of the elbow it is always a great advantage to have the plate in a plane parallel with that through the condyles of the humerus. The prominent inner condyle can always be felt, and if on account of swelling the external epicondyle cannot be felt, the position can be estimated with considerable accuracy by remembering its relation with the olecranon, which is always palpable.

Very often there will be flexion with anchylosis and inability to turn the humerus so that the condyles are in a horizontal plane without great discomfort. In such a case the shelf on

the radiographic stand may be tilted by means of the ball-bearing clamp until the plane of the plate is in a plane parallel with that through the condyles of the humerus.

Fig. 77.—Tube-holder with shelf and hand-rest arranged for making an antero-posterior view of condyles of humerus when elbow is anchylosed in a flexed position.

In case the limb is anchylosed in a flexed position it will be necessary to support the wrist and hand in some way, and keep it steady during the exposure. This may be accomplished

by an adjustable support, which may be fastened to the shelf as shown in figure 77.

Arm.—Radiographs of the middle third of the humerus can be most easily made with the patient lying on a table.

For an antero-posterior view the plate will naturally be placed under the back of the arm and will probably need to be propped up by blocks to bring it into close contact with the part.

For a lateral view it will be usually found most convenient to slip the plate between the arm and the side of the thorax, and direct the rays toward it in nearly a horizontal direction.

If two views are made from different directions it is well to remember that the humerus is capable of rotation at the shoulder-joint, and to be sure that the change in position of plate and tube is not compensated for by such a rotation. In case of injury to the arm and shoulder the bandages and splints which are used will very often make it difficult to properly place the plate, and much ingenuity may be required in order to obtain a satisfactory shadow without removing the dressings.

Shoulder-joint.—Owing to the position of the shoulder-joint at the side of the thorax, it is obviously impossible to obtain a radiograph in the lateral direction.

There are two methods of making antero-posterior views. The easiest one is to allow the patient to lie on his back with the plate under the joint, but in some cases this cannot be done without great discomfort. There are also cases in which the shoulder-joint is placed so far forward that it cannot be brought near the table in this position. For such a case the plate may be placed at the front of the joint and the tube behind. This may be done by having him lie face downward upon the plate, but it can be better accomplished by having him sit in a chair or stool and lean forward against a firm vertical support for the plate (as shown in Fig. 78). The movements of respiration may be communicated to the shoulder-joint, and it is therefore desirable to make the exposure short enough so that the patient can conveniently hold his breath while the radiograph is being made.

In radiographs of the shoulder-joint it will be desirable to show the anatomical neck and the greater tuberosity. In order

to do this to the best advantage the arm should be rotated so as to bring the anatomical neck in a plane approximately parallel to that of the plate. In doing this it is convenient to remember that the direction of the prominent inner condyle of the humerus corresponds very nearly with that of the anatomical neck.

The joint will be shown best if the plate is at the back, with the target of the tube at about the level of the glenoid cavity, and about 2 or 3 inches internal to it, the distance between the tube and plate being about 15 to 18 inches. If the tube is at the back, the target should be placed about 2 or 3 inches external to the glenoid cavity.

Fig. 78.—Dr. Cowl's plate support for radiographing thorax and shoulder.

Subluxation of the humerus will be shown satisfactorily by a single antero-posterior view.

In displacements of the head of the humerus in an antero-posterior direction a single radiograph may fail to show whether the head is displaced backward or forward. For such a condition it is useful to make stereoscopic radiographs according to the methods described elsewhere. Another way to determine whether the displacement is backward or forward is to make two radiographs, one with the tube in the position described above, and another with the tube moved outward about 6 or 8 inches from this position. If the displacement is forward, there will be in the first radiograph less overlapping of the shadows of the head of the humerus and the glenoid fossa than in the second. If the displacement is backward, the reverse will be true.

Scapula.—The acromion process will be usually shown very clearly in radiographs of the shoulder-joint made in the manner described above.

Fractures of the body of the scapula occur very rarely and will be easily shown by any antero-posterior view.

In order to show the body of the scapula to the best advantage it will of course be well to place the plate at the back, and to adjust it as nearly as possible in a plane parallel to that of the flat portion of the bone.

The coracoid process shows in the ordinary radiograph of the shoulder superimposed upon the shadow of the spine of the scapula, and therefore in order to obtain a radiograph of a fracture of this part of the bone it is better to place the source of the *x*-ray in front, and at a level considerably below the shoulder-joint, so as to throw the shadow of the coracoid upward and backward. With the patient lying on his back the plate can then be placed vertically and at the top of the shoulder. The arm should be abducted as much as possible and the tube should be placed at a level 10 or 12 inches below the shoulder-joint very close to the thorax. In order to avoid the risk of burning the part of the body which is nearest the tube a sheet of lead may be laid over the lower part of the thorax. If this sheet-lead is connected to a ground wire, the tube may be brought very close indeed without danger of burning or shock to the patient. Radiographs made in this way will show very little except the clavicle and the coracoid process. (See Fig. 79.)

Clavicle.—The clavicle can be best shown by placing the plate in front and as close to the body as possible with the tube behind. In fractures of this bone vertical displacements of the fragments will be shown in a single radiograph.

Antero-posterior displacements may be shown either by making stereoscopic exposures, or by making two radiographs with the position of the tube changed about 8 or 10 inches horizontally or vertically. If there is no antero-posterior displacement, the distance between the shadows of the ends of the fragments will be about the same in both radiographs. The end of the fragment whose shadow changes the most in

Fig. 79.—Radiograph by E. W. Caldwell showing coracoid process. Hammer Aurora plate, glycin developer. Water-cooled tube, target 18 inches from plate. Exposure six seconds (no intensifying screen).

position in the two radiographs will be further from the plate than the other.

It is well to remember that at the acromio-clavicular articulation there is a cartilage which casts no shadow, and the radiograph shows, therefore, normally considerable separation between the bones. The shadow of the end of the clavicle usually projects somewhat above the shadow of the acromion, and these appearances of the radiographs of the normal part might be mistaken for slight dislocation.

For showing the sterno-clavicular articulation the plate should be placed in front, and the tube at the back, a little to one side or the other in order to avoid superimposing the shadow of the spine upon the joint.

Foot.—Injuries of the metatarsal bones and phalanges will be easily shown by a single antero-posterior view. This can be made with the patient sitting in a chair with the sole of the foot resting upon the plate, which may be upon the floor, or supported upon a low stool or a block of wood.

In making a lateral view it will be well to place the tube in such a position that the shadows of the metatarsal bones will not be superimposed, and to place the plate at the side of the foot which is nearest the injury. The shelf which is attached to the tube-stand shown in figure 63 will be convenient for supporting the foot and leg.

Medio-tarsal Joint.—In making an antero-posterior view of the medio-tarsal joint the leg may be drawn inward and backward so that the tube can be placed directly over the joint in the position shown in figure 80.

Ankle.—The antero-posterior view of the ankle will show the lower extremities of tibia and fibula, and the surfaces of the astragalus with which they articulate, but it is practically impossible to show the os calcis in this position. It will be better to place the plate at the back of the ankle and the tube in front, directly over the joint. This radiograph can be made either with the patient lying down, or sitting in a chair with the foot and leg supported by the shelf mentioned above, using the hand-rest to clamp the ball of the foot so that it does not move from side to side.

A lateral view of the ankle will show the fibula better if the outer side of the leg is placed nearest the plate. If this radiograph is made with the patient in a sitting position, it will sometimes be necessary to place the plate in a vertical position and send the rays through in a horizontal direction.

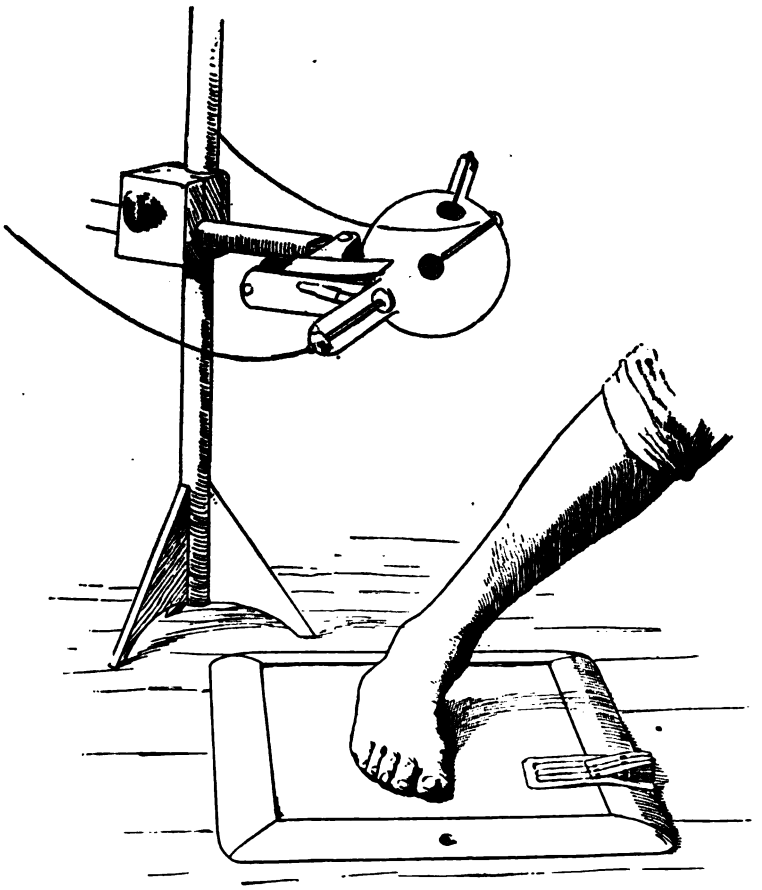


Fig. 80.—Method of making antero-posterior view of foot to show medio-tarsal joint.

When this is done, it will be convenient to rest the leg and heel upon a narrow block of wood in order to bring it well above the lower edge of the plate.

Leg.—The above suggestions for radiographing the ankle apply equally well for the leg.

Fig. 81.—Radiograph by E. W. Caldwell showing needle between ankle-joint and tendo Achillis.

In both the antero-posterior and lateral views it will be better to place the tube in such a position that the shadows of the two bones do not overlap.

In making an antero-posterior view the tube should be placed opposite the middle line of the leg. In the lateral view the shadows of the two bones will be separated if the tube is placed so that the rays pass a little diagonally through the leg; *i. e.*, a little in front of the leg if the plate is at the inner side, and a little behind if the plate is at the outer side of the leg.

Knee-joint.—Lateral views of the knee-joint show the tendon of the quadriceps extensor, the patellar ligament, the patella, and the other bones of the joint.

The antero-posterior views usually show the condyles of the femur, the head of the fibula, and the upper extremity of the tibia. The patella is superimposed upon the lower end of the femur, and usually shows only faintly unless the plate is placed in front of the joint with the tube behind. The semilunar fibro-cartilages cast little or no shadow, and displacements of these cartilages are not readily shown in a radiograph. Sesamoid bones are occasionally shown in some of the tendons back of the joint.

The antero-posterior view can be made most conveniently with the patient lying on his back, and the plate underneath the joint. If it is desired to show the patella, or if the joint is anchylosed in a flexed position, it will be better to place the plate at the front of the knee, the patient lying face downward.

Lateral views can be made with the patient lying on his side with the plate underneath the knee. There will be less danger of movement if the leg is flexed or semiflexed. The head of the fibula will be shown best when the plate is placed at the outer side of the knee. The articular surfaces should be accurately located in order that the rays may be passed directly through the joint. When the knee is very much swollen, this is not always easy. The lower extremity of the patella is a guide to the joint in normal subjects. When this landmark cannot be made use of, the joint can be located a little above the head of the fibula, which is always palpable.

Thigh.—Radiographs of the thigh will almost invariably be made either for examining fractures of the femur or for locating foreign bodies. The proper relation with tube and plate will easily be secured with the patient in the recumbent position.

Hip-joint.—The hip-joint of a large adult is a difficult subject to radiograph satisfactorily. A good radiograph of this part should show the head of the femur, the neck, and the greater and lesser trochanters distinctly. Owing to its position it is usually impossible to show the acetabulum very well. Radiographs of this joint will be useful in diagnosis of fractures, dislocations, and in diseased conditions of the bones. In old fractures there will almost always be an apparent shortening of the anatomical neck of the femur and the line of the fracture will be shown more or less imperfectly. Unless there is considerable deformity it will usually be impossible to judge how firmly the fragments have united. For obvious reasons it will be impossible to obtain lateral views of this joint.

Radiographs of the hip-joint will usually be made with the most comfort to the patient by having him lie on his back upon the plate with the tube above, but sometimes when there is a great deal of adipose tissue in the gluteal region the plate can be brought very much nearer the joint by placing it in front of the body, using a canvas-topped table, or allowing the patient to lie face downward on the plate. The tube should be 18 to 24 inches away from the plate, and at about the level of the crest of the pubes. It may be placed over the joint or directly over the median line. If both sides of the body are shown for comparison, the tube will, of course, be placed over the median line at the level of the pubic crest.

The anatomical neck of the femur will be shown best if it is rotated into a plane parallel with that of the plate. This will be done by turning the feet inward, strapping them together, and placing a block three or four inches wide between the heels to keep them apart. Sand-bags should be placed over the knees to steady the legs. This position of almost complete adduction of the thighs will be preferable in nearly every case, although sometimes it may be desirable or necessary to radiograph the joint with the thigh abducted.

This part of the body is so thick that it will be necessary to use a tube of moderately high penetration, but it must be remembered that tubes of too great penetration will not give contrasty pictures. A single radiograph showing the whole pelvis will usually be sufficient in cases of congenital dislocations. Stereoscopic pictures of the joint may be made, or the antero-posterior displacements may be shown by two radiographs made according to the methods described for the shoulder-joint.

Head, Face, Neck.—In this region we have to consider the skull, bones of the face, cervical vertebræ, larynx, pharynx, and upper parts of the trachea and esophagus.

Radiographs of the skull are usually made for locating bullets in the head and pieces of metal in the eye. For such injuries diagnosis with the *x*-ray will usually be satisfactory. It is sometimes possible to show in a radiograph fractures of the skull, and occasionally tumors or other lesions of the brain. Success in the diagnosis of such conditions depends largely upon the thickness of the skull, which varies greatly in different individuals. For determining the position of bullets in the head and foreign bodies in the eye special apparatus and technique are necessary, and will be described under the subject of localization of foreign bodies.

It has been mentioned before that exposure to the *x*-ray which is insufficient to cause burns may be enough to cause loss of hair from one side of the head, and great distress to the patient. Care must therefore be exercised to avoid over-exposure in this part of the body. The tube should be about 15 to 20 inches from the plate.

In radiographing the skull it is necessary to be very careful to support the head in such a way that it cannot roll. Especially is this necessary if two exposures are to be made in the same position for the location of a foreign body. When the condition of the patient will allow, the sitting posture will be convenient, the head being supported at the back by a right-angled arrangement of wood which may be attached to the head-rest of the regular surgeon's chair. Mackenzie Davidson has made a very convenient arrangement of this kind

which has an adjustable rest for the chin to aid in preventing movement of the head.

If the patient is unable to sit in a chair, he may lie on his back. For supporting the head in this position I have devised an adjustable sling of canvas which is shown in figure 82. This sling is adjustable in height to suit the comfort of the subject

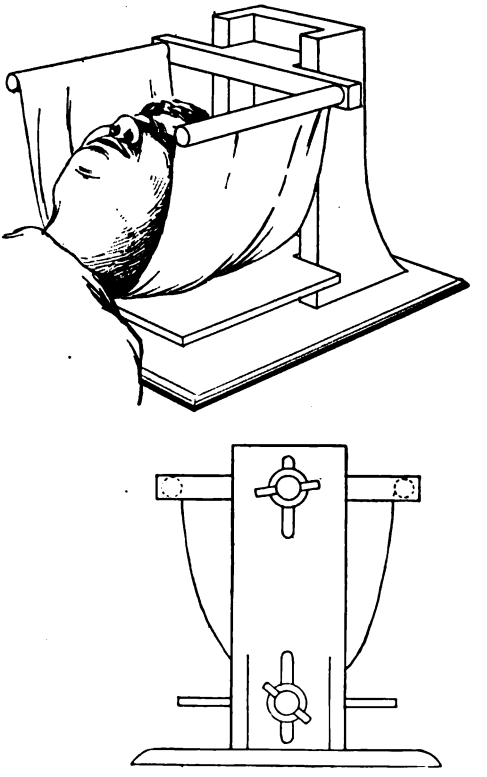


Fig. 82.—Canvas hammock for supporting the head in radiographic exposures.

and fits closely against the head so as to prevent rotation. It is pliable and makes a fairly comfortable pillow.

For making antero-posterior views with the plate at the back of the head there is an adjustable shelf for supporting the plate. For lateral view the plate is rested vertically upon this shelf, and the rays passed through the head in a horizontal direction. A convenient method of making antero-posterior

views with the plate at the front of the head is to use the canvas-topped table and place the tube underneath.

Face.—Radiographs of the bones of the face are usually unsatisfactory because the two sides are superimposed upon each other in the picture. The position which has just been mentioned for radiographing the skull will be equally convenient for the face.

Teeth.—Radiographs may be used satisfactorily for showing teeth which have not erupted, diseased conditions of the alveolar process, and foreign bodies such as pieces of drills, etc.

Radiographs showing the teeth may be made on glass plates in this position, and by properly placing the tube the shadows of the two sides of the jaws may be kept from overlapping. This will be easier if the mouth is kept open by a cork or piece of wood placed between the teeth. The tube may then be readily placed in such a position that one row of teeth will be shown without any other parts being superimposed upon it. The side to be radiographed will, of course, be placed nearest the plate.

A better way of radiographing the teeth, however, is to place within the mouth a small piece of photographic film enclosed in a water-tight envelope. The best film to use is the regular double-coated cut film, although the ordinary roll film used in hand cameras can also be used. The roll films are thin enough so that several layers may be used in the envelope, thus obtaining several negatives by the same exposure. For protecting the film against light and moisture one of the best materials is soft black dental rubber, which may be obtained from any dental supply house. This substance is opaque to light and fairly transparent to the ray. The thin sheets are soft and sticky, and readily sealed by pinching the freshly cut edges with a pair of pliers. The film may be placed between two sheets of tissue paper to prevent it from sticking to the rubber and then placed between two sheets of dental rubber. The sandwich thus formed may be cut to any desired size and shape with scissors, and the edges of the rubber pinched together, forming an envelope which is very little larger than the film it contains. The patient may hold the film with his

finger in the mouth behind the teeth which it is desired to radiograph. With this arrangement the exposure will be somewhat less than when the radiograph is made through the side of the face, and it should not exceed a few seconds.

Neck.—The upper three or four cervical vertebræ cannot be shown in the antero-posterior direction, because the shadow of the lower jaw will be superimposed upon them. In the lateral direction it is usually feasible to show the upper six cervical vertebræ. It is usually difficult to press the plate far enough down upon the shoulder to show the seventh.

Displacements of these vertebræ may be shown by stereoscopic methods, or by making two radiographs from different positions in the manner which has been described for other joints. In a good lateral view of the neck the cartilages of the larynx will show faintly, and the trachea will appear as a darker streak on the negative. The hyoid bone will be shown plainly, and there will be no difficulty in showing metallic bodies, such as pins and buttons, in this region. For radiographing the neck it will be convenient to use the support for the head which has been described before.

In order to show the lower cervical vertebræ it will sometimes be of advantage to place a bandage around the shoulder so as to press down the muscles running between the neck and scapula, and thus allow the plate to be placed in a slightly lower position.

Thorax.—Radiographs of the thorax give useful information of many abnormal conditions of the organs in this region. Areas of consolidation and cavities in the lungs due to tuberculosis will be readily shown; abnormal changes in the size, shape, and position of the heart and great vessels can often be demonstrated. Liquids in the pleural sac offer considerable obstruction to the *x*-rays and cast dense shadows.

The cartilages of the bronchi vary considerably in thickness in different individuals, and the shadows they cast in the radiograph have sometimes been mistaken for areas of consolidation in the lungs.

The interpretation of radiographs of this part of the body requires a great deal of experience and an intimate knowledge

of the pathology of these organs. This phase of the subject has been ably elucidated in the works of Holzknecht, BeClere, Williams, and others. Owing to the fact that the lungs offer very little obstruction to the *x*-rays, radiographs of the thorax may be made with much shorter exposures than are necessary for the abdomen and pelvis. On account of the movements of respiration, it is very desirable that exposures in this region should be very short: if possible, within the length of time that a patient may hold his breath comfortably. Radiographs of the thorax have been made with exposures of about one second by Von Ziemssen and Rieder, who use the method published by Rosenthal in the Müncher medicinische Wochenschrift, 1899, No. 32, and which is described as follows:

"Rosenthal employs a Volt-Ohm apparatus with a 60-centimeter coil, and electrolytic interrupter and Volt-Ohm tube. The time of exposure is essentially shortened by the use of two intensifying screens, the one being placed with its coated side against the coated side of the film, and the Schleussner film laid between the intensifying screens, the coated sides of which are toward the photographic plate. These are then enclosed in three light-tight envelopes. The patient lies on his belly or back upon the photographic plate, or the plate is placed upon the particular part desired to photograph and the current is opened for a moment and as quickly closed. The plates are then removed and developed in the usual manner."

Films coated on both sides require considerable pains in the development, and the intensifying screens also cause a certain amount of blurring or mottling which is especially noticeable if the exposure is a little too long. In ordinary practice, therefore, it would seem just as well to expose ten to twenty seconds (with the patient holding his breath), and use the regular double coated plates without any intensifying screens. Sharper pictures will be obtained, and the photographic manipulations will be simplified.

Position of the Patient.—Gravity has considerable effect upon the position of the thoracic viscera, and for this reason it is better to make the radiograph with the patient in the upright posture. One of the best arrangements is to let the patient

sit in a chair with the plate in a holder clamped between him and the back of the chair, placing the tube in front. Sometimes it will be desirable to make a radiograph with the plate in contact with the anterior wall. For such cases the patient may sit on a stool and lean against a vertical support for the plate. Dr. Cowl has devised a very good apparatus for supporting the plate in radiographic exposures of the thorax and shoulders. This arrangement is shown in figure 78.

Esophagus.—The *x*-ray is seldom, if ever, of any value in the diagnosis of abnormal conditions of the esophagus. The walls of this canal offer so little resistance to the *x*-rays that they cast no shadow. In order to show it, therefore, it has been suggested to introduce a rubber tube filled with mercury or shot, or to introduce bismuth subnitrate.

Spinal Column.—The usefulness of radiographs of the spinal column will depend very much upon the size and thickness of the subject. Usually they will be satisfactory for showing lateral curvatures and displacements, and in favorable cases they may show diseased conditions of the bones.

Radiographs of the dorsal vertebræ are usually more or less indistinct because of the shadows cast by the sternum, the liver, and the viscera of the mediastinum. All of these organs are rather opaque to the *x*-rays, and, except in favorable cases, it is impossible to show these parts of the spine with as much clearness as may be obtained in the lumbar region. The exposure should be long, and the development carried to a point which blots out the other structures of the thorax. The plate will, of course, be placed at the back of the patient and the tube in front. The density of the shadows of the superimposed tissues will be reduced by placing the tube as close to the front of the body as safety will permit, say at a distance of 6 to 8 inches from the skin. The patient may be placed either in a sitting posture, or he may lie on the plate; or in case the back is so tender that it is not comfortable to lie on the hard plate, he may lie face down upon a canvas stretcher and the plate may rest by gravity over the back, the tube being placed underneath.

Lumbar Vertebræ.—For radiographing the lumbar vertebræ

the plate will, of course, be placed at the back, and the tube in front and as near the abdomen as safety will permit. The plate should be developed to the point which blots out most of the other structures in this region. The penetration of the tube will have to be adjusted to suit the subject. A fair penetration will be necessary, but it is well to use as low a penetration as the thickness of the subject will permit.

Abdomen and Pelvis.—In the region below the diaphragm, radiographs may be satisfactorily used for showing the lumbar vertebræ, for detecting stones in the kidneys, ureters, or bladder, and for the location of bullets or other foreign bodies. In a few cases they may show gall-stones, enlargements of the liver and spleen, or may be used for obtaining measurements of the diameters of the pelvis, etc.

The stomach and intestines offer so little obstruction to the *x*-ray that ordinarily they do not produce any distinct shadows upon the plate. In order to show their outlines two or three methods have been suggested. One of these is to place in the organs some inert substance, such as bismuth subnitrate, which will cast a shadow. Another is to empty the canal of its contents, and inflate it with air, in which case the hollow spaces will show as dark spots on the negative. In case of the stomach perhaps the best way is to distend the organ with air, and insufflate with bismuth subnitrate by means of an apparatus employed by stomach specialists.

Usually it will be found that the antero-posterior view is the only one that can be made with satisfaction in this region. The patient may either lie on the plate, or upon a stretcher with the plate supported above him according to Shenton's method, or the plate may be placed underneath the stretcher as advised by Dr. Williams. Exposures for this part of the body will be among the longest that have to be made.

Radiographs of the pelvic region will be usually made with the most comfort by having the patient lie with his buttocks upon the plate and placing the tube above. The exact position of the tube will be determined according to just what it is desired to show. For stones in the lower part of the ureters a position should be chosen which will throw the shadow of

the stone between the shadows of the sacrum and the os innominatum. It may sometimes be impossible to show a stone in the portion of the ureter which lies opposite the ilio-sacral synchrondrosis, because its shadow may be obscured by the shadow of the pelvic bones.

A number of methods have been devised for obtaining from radiographic shadows the true dimensions of the pelvic outlet, but they are all more or less complicated and uncertain. Perhaps the best way is to determine the true position in space of the different points of the boundaries by methods which are used for location of foreign bodies, and determine the diameters by graphical methods.

Stones in the Bladder.—For stones in the bladder the best position is to place the patient lying face downward with the plate underneath the pelvis. Every means should be taken to cause the stone to occupy such a position that its shadow will fall above the shadows of the pubes. The table should be tilted so that gravitation will carry the stone forward and upward. The thighs should be somewhat abducted and the tube placed at a level well below the folds of the nates so that the rays will pass upward and forward through the true pelvis in a direction nearly parallel with that of the upper part of the sacrum. This will usually throw the shadow of the stone well above that of the symphysis pubis.

Stones in the Kidneys and Upper Part of Ureters.—It cannot be said that diagnosis of renal calculi by means of the *x*-ray is in all cases satisfactory. The difficulty of obtaining radiographs of kidney stones will depend upon the size and composition of the stone, and perhaps more upon the size of the subject.

Pure uric acid stones offer very little obstruction to the rays, and cast very faint shadows. It is possible that no radiograph will absolutely exclude the possibility of a uric acid stone. Fortunately, however, there is almost always present in these stones a sufficient quantity of oxalate or phosphate of calcium to cast fairly good shadows.

A good radiographic shadow of a stone may be taken as conclusive evidence of its existence, but except in favorable

subjects if the radiograph fails to show a stone its absence cannot be established with certainty. In general if the radiograph shows well the shadow of the twelfth rib, and transverse processes of the lumbar vertebræ, it is good enough to show a stone, and if in two or three such radiographs no stone is shown it may be taken as very probable that none is present.

The plate should be invariably placed at the back of the patient, and at least one plate should be made which covers both kidneys and which extends down far enough to take in the portion of the ureters above the ilium. It sometimes happens that stones are found on the side opposite to that in which the pain is felt.

In radiographing stones in the kidneys it is always advisable to use two plates, placing one on top of the other. It will frequently happen that the lower plate will be better than the one nearest the body, but the real reason for employing two plates is that with a single negative a spot may appear which might be due to a stone in the kidney, or to an accident in development. If the spot appears in the same position on two superimposed plates, the question is cleared up.

The tube should be placed directly in front, and may be in the median line; or if only one kidney is to be shown, a little to the right or left, at the level of the pelvis of the ureter. The movements of respiration cause more or less disturbance of this region; it is therefore desirable that the patient hold his breath during the exposure, which, under the best conditions, should not exceed one minute in duration.

Shenton prefers to place the patient face down upon a stretcher and rest the plate upon the back. This method has the advantage that a fluorescent screen may be placed over the plate and thus give a constant indication as to the character of the rays delivered by the tube.

If long exposures are made, Shenton's position has the advantage that it compresses the abdominal viscera, reducing somewhat the movements of respiration. A somewhat easier method is to allow the patient to lie on his back with the plate underneath, and place the tube above. This position allows the operator to watch the target of the tube to see that it does

not become overheated. It is obvious that the water-cooled tubes, as they are generally constructed, cannot be used in the position required in Shenton's method, for the reason that the water would flow away from the target and vapor or air collect in its place.

The contents of the intestines in front of the kidneys and ureters may cast shadows which help to make radiographs of this region indistinct. It has therefore been recommended to make the exposure after the intestines have been emptied as nearly as possible by purgatives and rectal irrigations. This, however, is an inconvenient and unpleasant procedure. A few months ago Dr. G. W. Roberts, of New York, suggested to me the idea of compressing into the abdomen over the region of the kidney a drum of material transparent to the rays, for the purpose of

Fig. 83.—Compressing the abdomen with gas ball for radiographing kidneys, vertebræ, etc.

reducing the thickness of the part through which the rays may pass. I have therefore devised two or three methods of carrying out this suggestion. One of these methods is illustrated in figure 83. A ball of very thin pure rubber filled with air and covered by fine netting is compressed, by means of a canvas band, deeply into the abdomen. It offers very little obstruction to the ray and probably compresses the contents of the intestines from those portions which lie underneath the ball. It also compresses the abdominal wall in this region, and in some cases the thickness of the part of the body through which the rays pass may be reduced as much as one-third. The same arrangement can be used with advantage sometimes in radiographing the lumbar vertebræ.

Gall-stones.—Radiographs showing gall-stones have been

Fig. 84.—Radiograph by E. W. Caldwell showing renal calculus in man twenty-eight years old, weighing 133 pounds. Hammer Aurora plate, pyrogallic acid developer. Müller heavy target tube, target 18 inches from plate. Exposure five seconds (no intensifying screen). Stone weighed 10 grains, chiefly calcium oxalate. Removed by Dr. Tilden Brown.

obtained by a number of operators, but it is fair to say that success in this work is obtained in a very small percentage of the cases. The material of which most gall-stones are formed offers very little obstruction to the ray, and they therefore cast very faint shadows. Moreover, the gall-bladder is so situated that in order to cast a shadow of this part the rays must pass through other viscera of considerable density. The best position is to place the patient face down upon the plate, bending the body backward by placing supports under the thorax and pelvis. This tends to push the gall-bladder below the free border of the liver. For the same reason it has been recommended to make the radiograph during full inspiration. The tube should be placed a little to the right of the median line, and opposite a point a little below the level of the free border of the liver.

LOCALIZATION.

The exact determination of the position of foreign objects in the body by means of the *x*-ray is a subject to which a great deal of work has been devoted, and a great many ingenious and excellent devices for this purpose have been invented

A single radiograph of a bullet in the abdomen gives very little information as to its depth and true space relations. The simplest method of determining the depth would be to make two radiographs from directions at right angles to each other—an antero-posterior and a lateral view, for example. For many cases this method will be sufficiently accurate, but it must be borne in mind that such methods will never be exactly correct unless the *x*-rays pass through the foreign body in a direction perpendicular to the plane of the plates—a condition which can be reached only approximately in practice, unless the body can be located first with the fluoroscope. There are many cases in which this will be impossible, and these are the very cases in which the greatest accuracy is necessary; for example, the determination of the position of small fragments of bullets in the head, and of small pieces of steel in the eye.

In the abdomen it may be perfectly easy to obtain an antero-

posterior view of a bullet, but difficult or even impossible to show it in a lateral view, and the only method therefore applicable to such a case is to make two antero-posterior views with the tube in slightly different positions and determine the position of the foreign body by triangulation.

In order to make this triangulation it is necessary to know accurately the distance of the source of the ray from the plate and the exact position on the plate of the foot of a perpendicular passing through the source of the *x*-ray. It is convenient to mark with a piece of metal wire some part of the body which is in direct contact with the plate. The position of the shadow of this wire will be the same in any position of the tube, and it is therefore a useful "landmark."

Mackenzie Davidson has worked out a very beautiful method of doing this work. This apparatus consists essentially of a tube-holder arrangement which enables careful measurements to be made of the position of the tube with reference to some known object on the plate. Two exposures may be made on the same plate, with thin subjects, but when the part is thick it will be better to use separate plates, and make a tracing from both plates showing the change in the position of the shadows of the foreign body due to the change in the position of the tube. This method was described in an article in the Archives of the Röntgen Ray, an abstract of which is given below:

"The theory of the method is essentially this: A Crookes tube is placed in a holder which can slide horizontally. A perpendicular is dropped from the point in the anode of the tube whence the *x*-rays originate on the point where the two wires cross each other at right angles, and one of the wires must be parallel to the horizontal bar along which the tube-holder slides, so that when a tube is displaced along the bar a perpendicular dropped from the *x*-ray point in the anode would always fall on this wire. The wires in reality represent two planes at right angles to each other, the photographic plate representing the third plane. Eventually I obtain the three coördinates of the foreign body from the three planes which are placed at right angles to each other and whose relation to the part of the person's body skiagraphed is known.

"For practical purposes it is convenient to have the wires stretched across a flat board or a sheet of vulcanite, which can be placed on the table in the correct position below the horizontal bar and fixed on the table by means of drawing pins. The wires being inked so as to mark the skin, a photographic plate enclosed in black paper in the usual way is placed beneath the cross-wires. The perpendicular distance from the anode to where the wires cross each other is carefully measured and noted.

"It does not matter very much to what distance apart the tube is to be displaced in order to take the two skiagrams—2½, 5 inches or more displacement may be given. Having decided this, the movable clips are so placed as to limit the sliding of the tube-holder to the required extent. The tube is then displaced to one side, and the patient places the part to be photographed on the cross-wires, being careful not to move, once the skin has come in contact with the wires, because it is of the utmost importance that the shadows of the cross-wires on the negative should register with the ink-mark left on the patient's skin. Further, it is convenient to put a small coin on one corner of the plate, and also a mark on the patient's skin nearest it. This reminds the operator as to the relation of the plates to the skin.

"One exposure is made, and the tube is displaced to the other side up to the clip, and a second exposure is given, on the same plate preferably, or upon a different plate provided a suitable apparatus be used to enable the plates to be changed without disturbing the position of the parts at all.

"Having developed and fixed the negatives, it will show a single shadow of the cross-wires, but two shadows of the foreign body. In order to interpret this correctly I devised the following apparatus, which may be called the 'cross-thread localizer' (see Fig. 85). A sheet of plate glass is fixed horizontally having two lines marked upon its surface crossing at right angles in the center. A mirror hinged below it allows the light to be reflected from below so as to render details of the negatives placed upon it visible by transmitted light.

"A scale fastened to a horizontal bar slides up and down

on two rods which support its ends. The scale has small notches opposite its marks. This is so placed that a perpendicular dropped from the 0 or middle part of the scale falls exactly where the lines cross on the glass at stage. Further, the edge of the scale is parallel to the line running right and left on the glass. The negative is now placed upon the glass stage, being careful to bring the shadows of the cross-wires into register with the cross on the stage, and placed with its marked quadrant in correct position. The gelatin surface of the plate can be protected by a thin transparent sheet of celluloid.

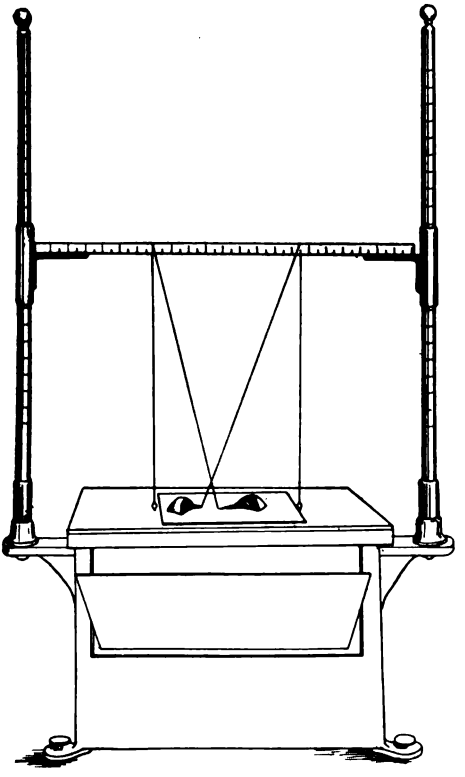


Fig. 85.—Mackenzie Davidson's cross-thread localizer.

"The scale is now raised or lowered so as to bring the 0 to precisely the same distance above the negative as the anode of the tube when the negative was produced. All that is now necessary is to place a fine silk thread through the notch on one side of the 0 on the scale and another thread through the notch on the other side exactly the same distance apart as that which measured the displacement of the *x*-ray tube.

"Small weights are attached to the ends of the two threads to keep them taut, while the other ends are threaded into fine needles fastened to a piece of lead. Thus the needle with the thread can be placed upon any point of the negative and

remain in position. In short, the negative is now relative to the cross-lines, the scale, and the notches from which the two threads come, exactly the same as it was to the cross-wires with Crookes tube when being produced.

"A needle with a thread is placed upon any point on one of the shadows of the foreign bodies, and the other needle is placed upon a corresponding point in the other shadow, and it will be found that the threads cross each other, just touching and no more. The point where they cross represents the position of the foreign body. A perpendicular can be dropped from this point to the negative below, and a mark made at the point where it touches the negative. Then with a pair of compasses the distance of this point from the two cross-wires can be measured.

"The height of the point where the threads cross gives one coordinate; that is, the depth of the foreign body below the skin which rested on the photographic plate. The other two measurements give the other two coordinates. It will be obvious that these measurements can be noted thus.

"As the mark of the wire is left on the patient's skin, all that is required is to measure the two coordinates on the skin that give the point below which the foreign body will be found at the depth given by the third coordinate."*

Davidson has applied this method to determine the position of foreign bodies in the eye.

Dr. Cowl, of Berlin, has recently published a new method of locating foreign bodies in the eye which consists in making one lateral view through the side of the head and another with the plate placed in the mouth, and the tube placed directly over the head so that the shadow is cast downward upon the plate and therefore shows the antero-posterior distance. In using this method it is, of course, necessary to place on the orbit or in some position near it wires or pieces of metal which may be used as guides in making measurements. The shadow will then show the position of the foreign body with reference to these metallic markers.

In locating foreign bodies in the eye it is important to prevent

* Archives of the Röntgen Ray, May, 1898.

rotation of the orbit while exposure is being made. This will be accomplished by having the patient look steadily at a fixed object several feet in front of him.

In practice it is exceedingly difficult to make measurements of the position of a tube with a tape-line or scale which are sufficiently accurate for use in determining the depth of a body by triangulation. To assist in determining the exact position of the tube I have been using for several years the simple apparatus which is shown in figure 86; it consists of two or more metal rods which are pointed at each end and held in a framework of wood or aluminum in such a way that they can be placed on a plate, and will be exactly perpendicular to

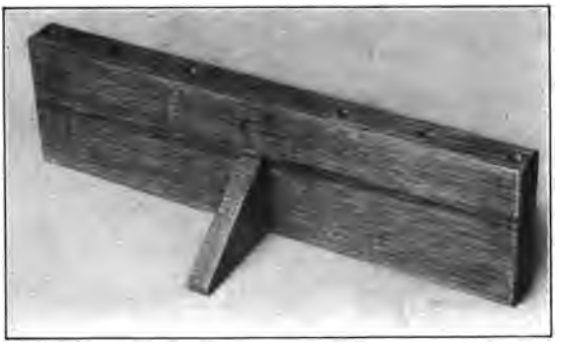


Fig. 86.—Wooden block containing pointed metal rods, for use in determining position of source of *x*-ray in locating foreign bodies.

it. When the radiograph is made, these two metal rods will cast pointed shadows on the plate which make an angle with each other. Now, if lines be drawn through the points of these shadows they will intersect in a point which lies at the foot of the perpendicular through the source of the *x*-ray. The distance of the source of the *x*-ray may be measured with fair accuracy by measuring with a tape-line the distance from the center of the target to the plate, but it may also be determined by calculating the altitude of the right-angled triangle whose base is a line between the foot of the perpendicular and the end of the shadow of one of these metal rods. This triangle will be similar to the triangle whose base is the shadow of

the rod and whose altitude is the length of the rod, both of which factors are known. If the two exposures are made on the same plate, the localization may be made very readily by using the Mackenzie Davidson cross-thread apparatus, adjusting the support of the cross-threads directly over the two points on the plate which mark the sources of the *x*-ray, and by carrying the lower ends of the threads to similar points in the two shadows of the foreign bodies. If the exposures are made on separate plates, it will be necessary to make a tracing which shows the two sources of the *x*-ray, the two shadows of the foreign

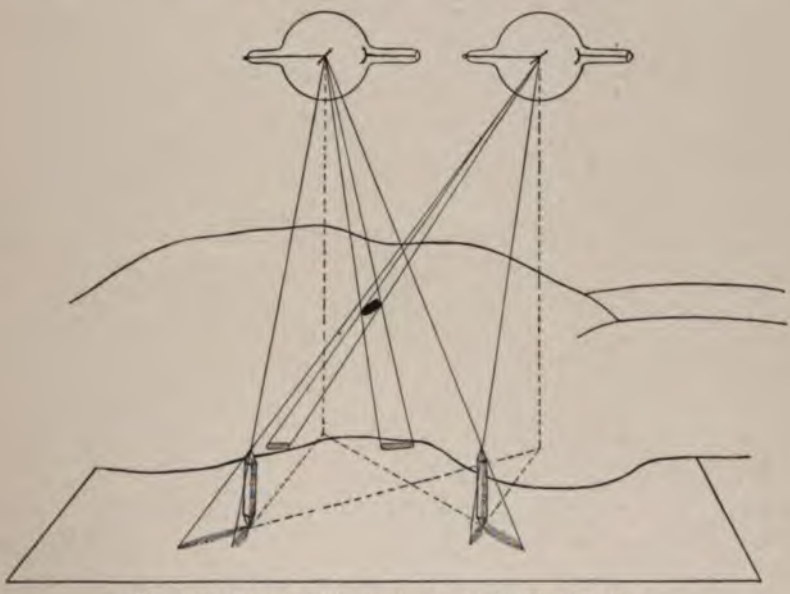


Fig. 87.—Diagram illustrating method of localization.

body, and the guide marker which is placed in contact with the plate, and whose shadow occupies the same position in both exposures. This guide mark is necessary in order to adjust the tracing to proper relation with the two plates.

The determination of space relation of the body with reference to the plate may also be made by simple graphic methods which will be obvious. A general idea of how the shadows enable the sources of *x*-ray and the position of the

foreign body to be determined is shown in figures 87 and 88. In order to refer the measurements on the plate to the surface of the body it will be necessary to place on some part of the skin which is in contact with the plate a mark whose position is shown in both plates. The mark on the skin may be made with tincture of iodin or silver nitrate which will remain after the part has been scrubbed for operation. If this mark is covered with a small piece of lead wire held in position by surgeon's plaster, its position will be shown on the photographic plate, and measurements can be referred to it.

Apparatus and methods for localization depending on the same principles have been devised by Borrell and others.

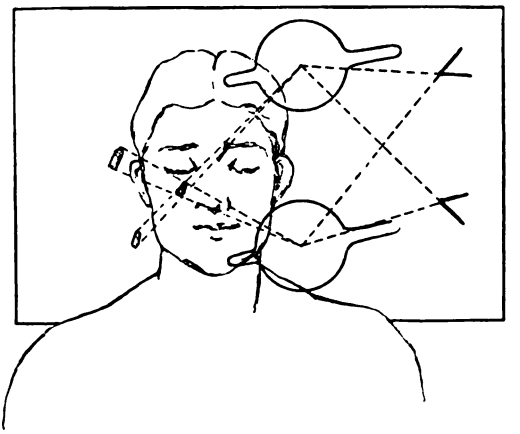


Fig. 88.—Plan illustrating method of localization.

Stereoscopic Radiographs.—It was pointed out by Elihu Thomson in 1896 that two radiographs of an object made by displacing the source of *x*-ray through a horizontal distance of about 2½ inches with the tube about 10 inches from the plate, would, when viewed through a stereoscope, give the appearance of relief. The value of such radiographs in showing the position of fragments of fractured bone or of a foreign object in the body will be obvious.

Mackenzie Davidson worked out a practical method of making such radiographs and used the Wheatstone stereoscope for viewing them.

In making stereoscopic radiographs great care must be exercised in two or three details. The two exposures must be made without any change in the position of the subject. This necessitates supporting it upon a thin substance which is transparent to the *x*-ray beneath which plates may be inserted or removed without disturbing the object. The two radiographs must be adjusted to a common level, which is as nearly as possible parallel with the line through which the source of *x*-ray is moved in the two exposures. Radiographs, unlike most photographs, rarely show points from which they can be accurately leveled, and it is therefore necessary to produce an artificial base-line by which they can be placed in the proper position for the stereoscope. The wrappings ordinarily used for *x*-ray plates are considerably larger than the plate, allowing considerabe shifting within them, hence it is impossible to use the edge of the plate as a base-line. I have developed at the Edward N. Gibbs *X*-ray Laboratory an appliance shown in figure 89 for making stereoscopic radiographs. The object to be radiographed is supported by a sheet of celluloid about $\frac{1}{16}$ of an inch thick stretched between supports on the base. On the base is a V-shaped guide on which slides a block carrying the tube-holder. A scale measures the distance through which the tube-holder is moved. Underneath the celluloid sheet and resting upon the plate is a strip of copper held loosely by two pins in such a way that its edge remains always parallel with the V-shaped guide, and therefore with the line through which the *x*-ray tube is moved. The tube-holder is in many respects like the one shown in figure 63, but it is supported on a block which slides on a V-shaped guide fastened to the base.

In using the apparatus the subject is supported by the celluloid sheet, the plate is slipped underneath this sheet and under the copper strip so that the edge of the copper strip casts a shadow at the margin of the plate. The tube is adjusted in such a way as to obtain a good radiograph of the part. The exposure is made, the plate is removed, and another one inserted in its place, and the tube-holder moved by means of the sliding block through the desired distance, which will be indicated on the scale. Another exposure is made in the same way. The

copper strip above referred to is perforated at two or three points with small apertures whose shadows enable corresponding points on the two plates to be referred to each other. This apparatus may also be used with great advantage in making

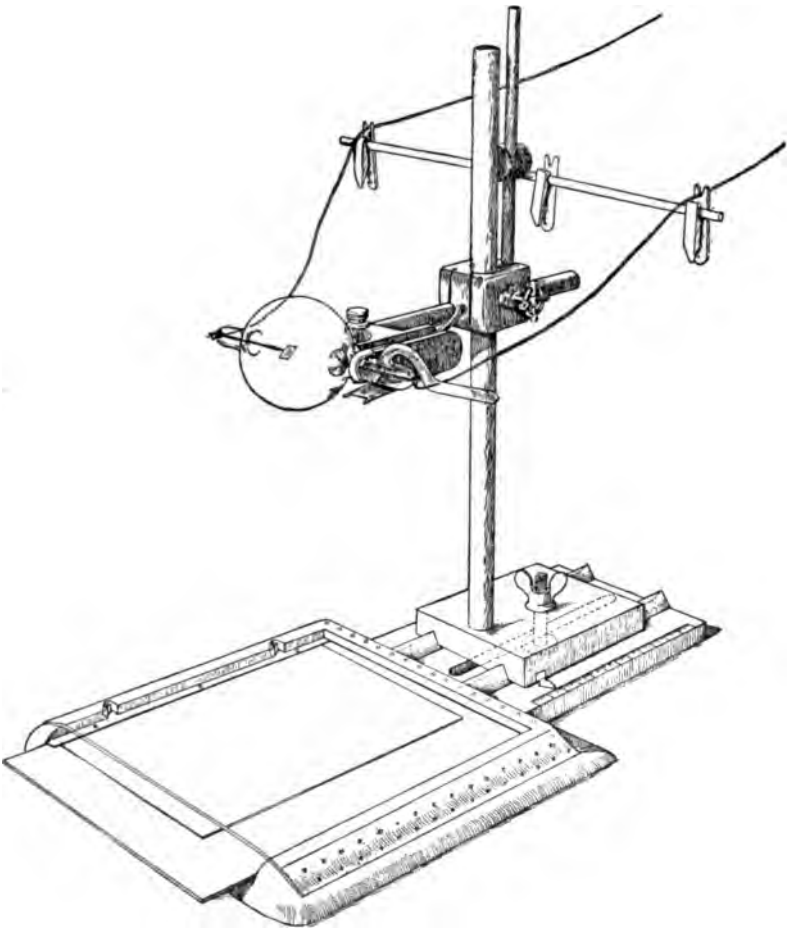


Fig. 89.—Apparatus for making radiographs for use with the stereoscope or for location of foreign bodies.

two exposures for locating foreign bodies after the method described above. In fact, two stereoscopic plates may be used with Mackenzie Davidson's localizer for this purpose. Localization, however, will be more accurate if tube is moved through

a greater distance than will be advisable for obtaining stereoscopic effects.

Owing to the large size of plates necessary for radiographic work, stereoscopic radiographs must be viewed through some special form of stereoscope, or reduced to proper size for the ordinary stereoscope. For the ordinary stereoscope the picture should not exceed 2½ inches in width, and the reduction of large radiographs to this size takes a great deal of time and trouble. Wheatstone's stereoscope is almost universally employed for observing the large pictures.

Two excellent types of this stereoscope have been devised by Dr. L. A. Weigel, of Rochester, and Dr. Alexander B. Johnson, of New York city. The Wheatstone stereoscope consists of two

Fig. 90.—Weigel's modification of the Wheatstone stereoscope.

mirrors placed at right angles to each other, with an arrangement for supporting the pictures, so that an observer who places his eyes opposite the two mirrors will see one picture with one eye and the other picture with the other eye. Dr. Weigel's arrangement (see Fig. 90) has a very good means for varying the intensity of the light, by shifting the distance of the incandescent lamp from the negative, which accomplishes the result without any change in the color of the light and enables two negatives of unequal density to be equally illuminated. Dr. Johnson's instrument has a bellows, which excludes reflected light from the negative and therefore makes it possible to use the apparatus in a room not completely darkened.

Interpretation of the Negative.—Radiographs differ in many essentials from other pictures, and skill in interpreting them can be acquired only by considerable experience. It may be useful here to mention a few points which must always be considered. It has been stated before that a radiograph must always be considered as a shadow of the part, and not as a picture. In a good radiograph the shading, due to varying thickness and varying penetrability of different parts of the subject, often gives an appearance of perspective which may be quite misleading. A little practice with the skeleton and incandescent lamp mentioned in the earlier part of the chapter will often be of great value in helping correctly to interpret a radiograph.

In cases of fracture and dislocation in which the mere idea of position is all that is sought the interpretation will be fairly easy, but for determining the nature of diseased conditions much more judgment will be required.

Malignant diseases of the bone invariably cause them to become more transparent, the ray thus producing in the negative dark spots, and in the print light spots. In nearly all advanced malignant growths of the bone a pushing-out of the periosteum will be shown. In tubercular bones there will be greater transparency and a peculiar lack of contrast of the bones with the flesh which will be readily recognized with a little practice. Very often in bone injuries of long standing there will be an increase of transparency due to a thinning of the compact tissue which results from a lack of nutrition. In these cases it may sometimes be difficult to distinguish between a tubercular bone and one in which there is atrophy due to lack of nutrition. In bone atrophy there is less disturbance of the structure of the cancellous tissue.

Careful attention to methods of localization will prevent errors in determining the position of foreign bodies by the *x*-ray.

CHAPTER VII.

THE PHOTOGRAPHIC MATERIALS AND THEIR MANIPULATION.

It is probably true that as many unsatisfactory radiographs are due to improper manipulation of the photographic plate as to improper exposures to the *x*-ray. Some radiographers entrust the development of their plates to the professional photographer or to a more or less unskilled assistant. Occasionally one may find a photographer who is skilful enough and careful enough to obtain good results from *x*-ray exposures, but such men are rare exceptions. In order to obtain the best results, as well as to avoid annoying delays, risk of breakage, etc., it is necessary for the Röntgen worker to develop his own plates, or at least to have them developed by a skilled assistant under his immediate direction. The development of a radiograph does not differ in many respects from that of an ordinary photograph, and as there are so many excellent books on photographic development, I shall take up here only a few points which relate especially to radiographic work.

Plates.—Any good photographic dry plate is suitable for radiographic work, and there is very little choice between the best grades of the plates of the best makers. The rapidity of dry plates for *x*-ray exposures bears some relation to their rapidity for camera exposures, but for the *x*-ray there is not so great a difference between the very fast and the very slow plates. The best results seem to be obtained on plates of medium or fast speed, such an "Hammer Extra Fast," "Cramer Banner," "Seeds 26X or 27." Double coated plates offer some advantage, and these are sold usually as non-halation plates by most of the makers. The Hammer Aurora I have found to give excellent results where it is desirable to use a double coated plate. With the double coated plates there is some gain in the matter of shortening the exposure, and apparently

there is greater differentiation of the tissues when they are used for radiographing the thicker parts of the body; for example, in cases of renal calculus, etc. Celluloid films may often be used with advantage for *x*-ray work, but they have not the keeping qualities of glass plates, and for this reason are not so reliable. Celluloid film, however, has the advantage of being exceedingly transparent to the *x*-ray, and because of this and because of its thinness it is quite feasible to enclose a film between two intensifying screens and thus reduce the exposure more than is possible with a single intensifying screen and a glass plate. In Germany these films are made by Schleussner for *x*-ray work, having a double coat on each side, making in all four coats. Such films are intended to be used between two intensifying screens as described above. The development of such films is exceedingly tedious and requires arrangements which more than compensate for the gain in speed obtained.

For radiographing the teeth it is very convenient to use a celluloid film encased in a water-tight covering and placed in the mouth as mentioned in Chapter VI. For this purpose the Seeds double and triple coated films are very well adapted, and are much better than the thinner roll films supplied for hand cameras. The very fast bromide papers may also be used instead of plates, thus giving prints directly. They offer so little obstruction to the ray that a dozen or more of them may be laid up in a pile and exposed all at once. The bottom sheet will give about as good a picture as the top one. These bromide papers, however, do not give as good results as may be obtained on films or glass, and their use is not recommended. Several makers put out *x*-ray plates, or plates especially intended for *x*-ray work. I have not found any of these, however, which present any advantage over the regular photographic plates, and I prefer not to use them, for the reason that the demand for them is comparatively small and consequently they are liable to become old before the dealer disposes of them.

It is very important that the plates or films used in radiographic work should be fresh, and it is much easier to obtain

fresh plates of the sort which are used for general photographic work than of those which are sold only for *x*-ray work.

Size of the Plates.—For convenience in filing away and preserving the negatives it is well to adopt a few standard sizes, and to use always one of these sizes. The size to be used will be determined, of course, principally by the parts to be radiographed, but it is a good idea to adopt the sizes which are in greatest demand for camera work. These sizes are the ones which are most readily obtained fresh. It happens that nearly all of my work is done on two sizes of plates: viz., 8 × 10 and 11 × 14. In addition to these sizes I have always on hand plates 5 × 8, and 14 × 17. Practically all of my work is done on plates of these four sizes. Occasionally a plate 18 × 22 is used, but such a size is rarely, if ever, necessary. Consideration of expense naturally leads one to use as small a plate as possible, but it is as well not to carry this point too far. Development is easier when there is a reasonably good margin outside of the picture, and by using a large plate very often we may detect an injury which was out of the region in which the trouble was suspected.

Keeping the Plates.—It must be borne in mind that the *x*-ray passes through walls, and doors, and boxes, and that if a stock of photographic plates is kept within thirty or forty feet of the room in which powerful *x*-ray tubes are used frequently, it is as well to protect them against stray rays. For this purpose I use a wooden box or cupboard, covered on the outside with ordinary plumbers' sheet-lead to the thickness of about $\frac{1}{8}$ of an inch. The plates are less liable to be scratched or damaged if kept standing on edge. The cupboard is therefore provided with vertical partitions and shelves to accommodate the plates of different sizes. Two compartments are reserved for the plates which have been placed in the envelopes ready for exposure, and for the exposed plates which await development.

Developers.—There are so many good developers that it is impossible to say which is the best for *x*-ray negatives. In a general way, it may be stated that those developers which give contrast are usually to be preferred. This

property may lie in the developing agent itself, or it may be due partly to the proportions of various ingredients used in the developing mixture. It is well to become accustomed to one good developer and not to change. It may be truly said that the developer is best which one knows best how to use. Undoubtedly the best results in radiographic work are obtained with slow development, although excellent results are obtained by many workers with more rapid developers, such as metol, rodinal, etc. My own preference is for pyrogallol, which I mix according to the following formula.

Formula.—

Solution No. 1:

Distilled water	24 oz.
Oxalic acid	15 gr.
Pyrogallic acid	1 oz.

Solution No. 2:

Sodium sulphite solution, sp. g. 80.

Solution No. 3:

Sodium carbonate solution, sp. g. 40

To develop take:

Solution No. 1	1 part
Solution No. 2	1 part
Solution No. 3	1 part
Water	2 to 4 parts.

In Germany some of the best workers prefer glycinamid. The formula recommended by von Ziemssen and Reider, who have done some of the fastest and best radiographic work that has as yet appeared, is as follows:

(*a*)	Glycin	40.0
	Potassium carbonate	40.0
	Sodium sulphite	150.0
	Distilled water, hot	1000.0
(*b*)	Potassium carbonate	100.0
	Distilled water	1000.0

For use, mix equal parts *a* and *b*.

The advantage of glycin is that development with it may be carried to almost any extent without producing fog. It is very slow in its action, and some workers use it in a vertical tank very much diluted, leaving their plates in this dilute

developer for from one to three hours. If the plate is properly exposed, it may be immersed in the developer and removed at the end of two hours with good results. Obviously, though, it is much safer to watch the plate during development, or at least to look at it from time to time.

Prepared developers are not to be recommended for radiographic work. It is much better to buy the purest chemicals obtainable and to make the developer yourself with distilled water. It is especially important to obtain pure sodium sulphite. This important ingredient of almost every developer is very liable to contain impurities, principally sodium carbonate, in varying amounts. In order to obtain uniform results, therefore, it is necessary to use the best chemicals obtainable and to use always the brand to which one is accustomed. Good negatives are obtained by so many widely different methods of development, and so many developers, that it is impossible to mention them all here. It will be sufficient to describe one method of development with one developer: viz., pyrogallol. Referring to the formula given above, it will be seen that three stock solutions are called for. These should be kept in glass bottles with well-ground stoppers, and these bottles should never be allowed to become nearly empty. The pyro solution (No. 1) is especially liable to deteriorate by contact with the air. The addition of the oxalic acid, however, helps to preserve it, and in tightly stoppered bottles it may be kept for a week or two in good condition.

In mixing the carbonate and sulphite solutions for a developer, the hydrometer will be found to give more accurate results than can be obtained by weighing the chemicals. A convenient way is to keep on hand glass-stoppered bottles full of saturated solutions of the sodium carbonate and sulphite. When it is desired to make up solutions No. 2 and No. 3, these saturated solutions are diluted in a graduate with water until the proper hydrometer reading is obtained. The stock solution bottle is then filled from the graduate and the bottles containing the saturated solution are filled completely by the remaining liquid in the graduate and the addition of more water and salts.

Developing the Plates.—The temperature of the developer is a matter of great importance. If it is too warm, the plates are likely to fog; and if too cold, the development proceeds very slowly. If possible, the temperature should not be allowed to vary beyond the limits of 65° and 70° F. In the summer-time it may be often found necessary to cool the developer with ice. This may be done by putting a little cracked ice in the solution, but a better way is to ice the developer in the bottle, after the manner of a bottle of champagne, until the temperature is 60° F. The temperature of the solution will quickly rise to 65° or 68° F. when it is poured upon the developing tray and the plate, which are somewhat warmer.

In developing the dry plate it should be borne in mind that it takes some little time for the liquids to soak up the emulsion so that the developing agent can reach all of the silver salts in the film. If we start developing with a strong solution, the superficial parts of the film which are first exposed to the action of the developer will be acted upon before the solution has a chance to reach the deeper parts. It is therefore my practice to begin development with a solution containing Nos. 1 and 2, and very little carbonate. With this mixture development is continued for about six to ten minutes, during which time the emulsion will have become soaked up. The carbonate of soda is then added in small portions from time to time as the development proceeds. If the plate is over-exposed, only a small amount of carbonate will be needed. Restraining the development by reducing the amount of carbonate seems to give better results than the use of bromide of potassium, although in cases of over-exposure it will be necessary to use bromide with plenty of carbonate in order to obtain the best results. Development is continued in this way for from fifteen to fifty minutes, keeping the solution moving by rocking the tray and keeping a close watch on the progress of development. With an *x*-ray negative development may be continued for a much longer period than would be advisable with a camera exposure, and the usual error of the professional photographer in developing an *x*-ray negative is that of under-development. The problem of determining just when development has been

carried far enough is an exceedingly difficult one. It is a thing which must be acquired by practice and about which written directions are of little use. In order to obtain sufficient density of the negative it is usually necessary to proceed with development until the plate is perfectly opaque to the ordinary ruby light of the dark-room lamp. Success in the development of *x*-ray negatives requires a great amount of patience and skill. This part of the work is not less important than that of making the exposure, and must be attended to with the same care that is needed for the other part of the work.

Fixing Baths.—After the development is complete the plate should be washed two or three minutes in several changes of water and then placed in the fixing bath. The ordinary fixing bath is simply a solution of about one part of sodium hyposulphite to four or five of water. Such a fixing solution does not keep long and must be renewed frequently. Some photographers use with the hypo solution an alum mixture, for the purpose of preserving the solution and hardening the film. The formula of one of these alum baths is given below:

(*a*) Water	96 oz.
Hypo	2 lbs.
Seeds' c. p. sulphite of soda	2 oz.
(*b*) Water	32 oz.
Chrome alum	2 oz.
Sulphuric acid	¼ oz.

Pour *b* into *a*, while stirring *a* rapidly. As the chrome alum dissolves slowly, a stock solution of *b* can be made up.

These alum baths are more or less unstable, and chemical changes sometimes occur in them which produce bad effects upon the plates. The most convenient fixing solution I have found consists of the sodium hyposulphite solution, about 1 : 4, to which is added one ounce of a saturated solution of sodium bisulphite (acid sulphite of soda) to 16 ounces of the hypo solution. Such a bath will remain clear for a long time (I change mine about once a month), and it has a hardening effect on the film. The fixing process will require usually from five to twenty minutes. With the double coated plates, the time required for thorough fixing is long. Plates should be

allowed to remain in the fixing bath for two or three minutes after every trace of unreduced silver salts has disappeared from the film. They should be then washed in running water for forty to fifty minutes, when they are ready to dry. In drying plates it is well to remember that the water drains from them better if thy are supported in such a manner that one corner is lowest.

The Dark Room.—The development of the small plates which are used in the ordinary hand camera may be done conveniently in a dark closet or in any room that can be properly darkened, but when the large plates necessary for radiographic work are used it is very desirable to have plenty of room. Running water is almost indispensable to the dark room, and it is very convenient to have a large soapstone sink, large enough to contain a number of developing trays at once, so that several plates may be developed at the same time. The sink is much preferable to a table for holding the developing trays for obvious reasons. Next to the running water, perhaps, the greatest comfort in the dark room is an electric light circuit. The uncertainty of oil lamps, the necessity for trimming and refilling them, their variations in intensity, and the unavoidable odor are points which need only be mentioned. The light of an incandescent lamp is comparatively constant, requires the minimum attention, and does not vitiate the air of the dark room.

Figure 91 shows a ruby lamp which I have designed for the dark room of the Edward N. Gibbs *X*-ray Laboratory and which has been very satisfactory. Two 16-candle-power incandescent lamps of ruby glass are enclosed in a wooden box with an asbestos lining. One face of this box, which is 8 by 10 inches, is covered with a plate of ruby glass, a plate of orange glass, and lastly a plate of ground glass. The box is supported so that is may be rotated on its horizontal axis or a vertical axis. It thus has all the movements of a search-light, and its light may be directed to various parts of the dark room or upon the plates, or away from the plate toward the wall. It is, of course, desirable to expose the plates as little as possible even to the ruby light, and the advantage

of being able conveniently to turn the light from the plates will be apparent. In addition to these movements of rotation, this ruby lamp is arranged to slide backward and forward along a wooden track, which is held by brackets above the developing sink along its whole length. It may thus be moved in various positions to examine any one of trays in which the process of development is going on. The rocking of the developing trays during a long tedious development becomes very

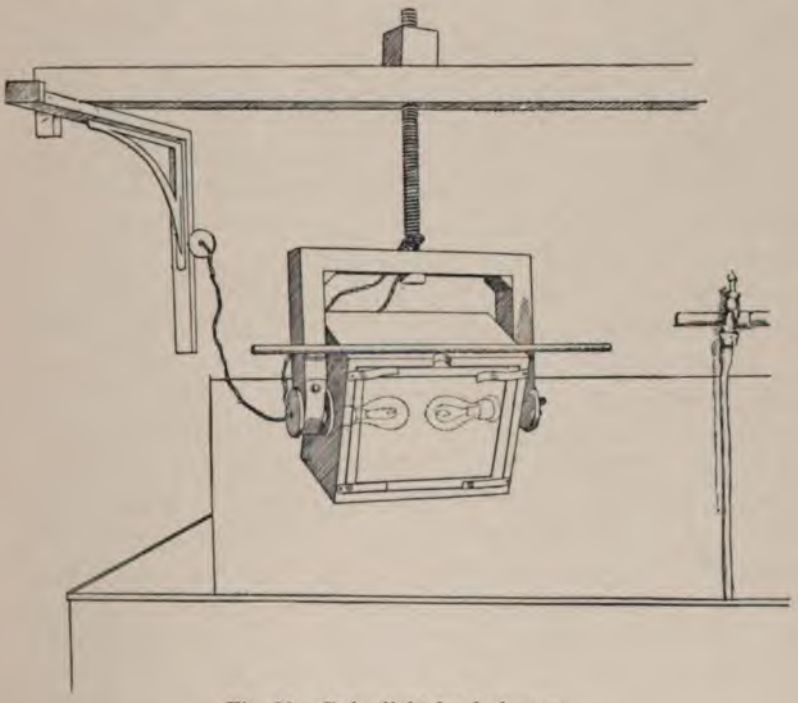


Fig. 91.—Ruby light for dark room.

tiresome, and a number of automatic rocking devices have been used. One of the simplest is that in which the support for the tray is connected with a long heavy pendulum, which when once set in motion, continues to swing for a considerable time. Some operators use a vertical developing bath instead of trays, and place in it a number of plates, circulating the liquid, by various means.

If only a few plates are to be developed, the fixing solution may be used in an ordinary developing tray; but if it is desired to fix several plates at a time, it is a great convenience to have a vertical fixing bath slotted to hold the plates of various sizes and provided with a cover which may be closed to exclude the light after developing is finished. For washing the plates a slate or metal-lined wooden tank with vertical slots for accommodating the various sizes of plates will be found very convenient. The water should be allowed to flow in at the bottom of the tank and overflow should be at the top. A space must be left between the bottom of the tank and the lower edges of the plates, to allow the water to circulate freely between them. For the same reason the level of the water should extend for an inch or more above the top edges of the plates.

In the dark room it will be found convenient to have shelves for the various chemicals, a good balance for weighing the chemicals, a hydrometer, thermometer, filter-paper, mortar and pestle, glass funnels, and such appliances as will suggest themselves to every one who has had to do with chemicals.

Rubber Gloves.—Many developers stain or poison the hands and skin, and it is therefore a good idea to use rubber gloves during the development. With a little practice one becomes accustomed to these rubber gloves and they are not inconvenient. Care must be taken to wash the hands or rubber gloves carefully after putting a plate in the fixing bath and before handling another plate in the developer. A very small amount of the fixing solution will interfere seriously with the development.

Printing.—The printing of an *x*-ray negative does not differ essentially from that of an ordinary negative, and therefore it needs no description here. It is a matter which may be safely left to the ordinary photographer, and most operators will doubtless prefer to do this. Moreover, it is impossible to get in a print all of the detail which may be seen in an *x*-ray negative, and in the majority of cases the negative alone suffices. If the printing is to be done by the operator, it is probable that the developing papers will be preferred on account of the smaller amount of time required for handling them and the

matter of being independent of weather. In cases in which it is desired to have a print at the earliest possible moment, it may be made from the wet negative in the following manner. The negative is placed in a tray of water; a sheet of printing paper is then carefully wet and placed against the sensitive film under the water. The plate is then removed with the paper in contact with it and the surface of the glass is carefully wiped dry and free from streaks. The print may then be made with an incandescent lamp or gas-jet in the usual way. For such work as this, developing papers like Cyko, Velox, etc., are excellent. The glossy papers give greater detail and are therefore better for *x*-ray negatives.

Some of the best radiographic prints I have seen have been made by Dr. E. R. Corson, whose method is described in the Annals of Surgery for October, 1901, from which I quote the following:

"One of the disappointments in *x*-ray work is the great inferiority of the print compared with the negative. A good sharp negative, with much of the bone detail, viewed by transmitted light, seems to leave nothing to be desired, and yet, when we print from this negative, disappointment is sure to follow. What is the main cause of this? It is because of the inequalities of the negative, an inequality which does not exist to anything like the same extent in the ordinary camera negative. When there is but little difference in the thickness of the parts skiagraphed, this inequality is slight; but if, as is usually the case, the thickness of the bones and soft parts varies much, the inequality in the negative becomes considerable, and is the disturbing factor in the printing, the thinner parts of the bone being over-exposed in comparison with the thicker parts. You have a negative which is both dense and thin, and in attempting to print from such a negative the denser portions are too faint or do not appear at all, and the thinner parts are too dark, and in both cases the detail suffers; in the first instance it is too faint, in the second the detail is smothered up in the deep shadows. And, really, the finer your negative is,—that is, the more detail you have,—the more does this fault show up in the print.

"For some time I have been trying to overcome this difficulty, and generally unsuccessfully. My usual method has been to use a shaded ground-glass screen, or, better still, the passing of the hand during the printing over the thinner parts of the negative to retard the printing at these points. This was the method used with my prints of the epiphyses; but it is very uncertain, very irksome, and much printing paper is wasted.

"In some recent work I have made use of a photographic trick sometimes used by professionals in portrait work, which seems to me to have solved the problem. It consists in the following manœuver: The back of the plate having been cleaned of all spots and finger-marks, it is evenly and carefully flowed with a preparation known as 'Hance's ground-glass substitute,' a solution of certain gum resins in ether. Great care must be taken to prevent the solution from running onto the film side, otherwise you may ruin your negative. This requires some little practice to do properly. I have found that if you will smear the edge of the plate with vaselin, you are less liable to meet with this unfortunate accident. This ether solution, of course, evaporates rapidly, leaving a very thin coating of gum resin, which adheres to the plate with great tenacity, presenting a surface difficult to distinguish from ground glass. You have now a surface into which you can rub any pigment and which will stick. With an artist's stub, such as is used in charcoal work, you carefully by transmitted light rub into the thinner parts of the negative burnt umber or burnt umber and yellow ocher. If properly done, you do not rub out the faintest hair-line of detail; you simply even up your negative. It is well, before this process is undertaken, to take an ordinary print from the unprepared negative, and this will show you the inequalities and those portions which require the pigment backing to retard the printing. This process is also very valuable when you wish to make enlargements, difficult ordinarily on account of this same inequality. In this instance you can make a very even positive from which you get the enlarged negative, and which is just as even as the positive and the original negative. One can, of course, get an even negative of the same size as the original one by making a posi-

tive, and from this making a negative again, thus having a plate which requires no backing, and which can be preserved without the danger of the backing rubbing off, as in the first instance.

"By this process, then, you obtain an even negative without touching the film side, and without changing in the slightest degree its detail. It admits of any amount of careful working up, for you can constantly test your backing by a print, lighting it here and making it denser there, until the print comes out with all the detail preserved, and with the greater part of the beauty of the negative intact. Of course, there is a certain depth of film on the negative viewed by transmitted light which no print can give, but the real essential detail is there, just as in any ordinary photographic print."

The method described above is free from most of the objections that can be brought against retouching the negative, because what is done is really to so control the light that each part of the negative shall be printed to best advantage, and there is little or no risk of falsifying the record, as is the case when the negatives are retouched.

Another method of accomplishing the same result is that of using what is known among photographers as the brush development. The developer is applied to the printing paper by a fine camel's-hair brush, and the density of the different parts of the print is controlled by regulating the amount of the development in different areas. Success in this manipulation requires a great deal of skill. The method advocated by Dr. Corson is certainly much easier, and has the advantage that when the negative is once prepared any number of prints may be made from it without further trouble.

CHAPTER VIII.

THE CHOICE OF AN X-RAY OUTFIT.

In the preceding pages much has been said about the various appliances that make up the *x*-ray outfit, and about those features of them which are desirable and those which are undesirable. In regard to the choice of auxiliary appliances it is not necessary to say anything further than to advise the purchase of those of the best quality that can be obtained. The problem of choosing an outfit then resolves itself mainly into the question of what type of exciting apparatus to employ.

The choice of an exciting apparatus will depend largely upon the class of work which it is intended to do, and upon the character of the available source of electrical energy.

For those who have not determined just what use they will make of an *x*-ray outfit, a few hints as to what they may reasonably expect to do with it may be helpful.

Many people suppose that all that is necessary in order to do any sort of *x*-ray work is to buy an outfit and "press the button." This is far from true, but any one with a reasonable amount of patience and skill, and with proper apparatus, may make satisfactory fluoroscopic examinations of the extremities and of the thorax, and may, with a little more trouble and experience, make fair radiographs of the extremities and thorax. He will very readily learn to operate the tubes for the therapeutic application of the *x*-ray. Thorough *x*-ray examinations of the shoulder-joint, the abdominal and pelvic regions, and the hip-joint can be made only by means of the radiograph. Radiographs of these parts are infinitely more difficult to make than of the extremities or the thorax. It is quite probable that the average physician will not want to take the time and trouble to perfect himself in the art of radiographing the difficult parts of the body. In justice to both himself and his patient it will be better to have this sort of

work done by a specialist who has had a large experience and who keeps a suitable equipment for this kind of work always ready for use.

The prospective purchaser of an *x*-ray equipment will be confronted by a bewildering diversity in kinds of apparatus offered for sale and conflicting claims as to which type of machine and which make of any particular type is best. Advice from men who have been doing *x*-ray work will probably be as conflicting as that from the dealers who have apparatus to sell. The man who has been successful with the static machine and has not used the induction coil will probably say that the static machine is far superior to the coil for every kind of *x*-ray work. There are hundreds of competent workers who say that the induction coil is the only proper exciting apparatus for the *x*-ray tubes. There are some who have used the high-frequency apparatus with satisfaction and who recommend it strongly.*

Successful work has been done with all these various forms of apparatus, and much bad work has also been done with them. Some men discard the static machine for the induction coil and get better results, others discard the induction coil for the static machine, with a like improvement in results.

The high-frequency outfits are, for reasons which have been mentioned, much inferior to both the static machine and the induction coil for every kind of *x*-ray work. They are not at all suitable for difficult radiographic work, although they may be used for the easier diagnostic work and for therapeutic purposes. The only possible reason for employing the high-frequency outfit is that it can be readily operated from the alternating current lighting circuits. However, even when no other source of energy is available, the two other types of exciting apparatus will be preferable.

Apparatus for 110-Volt Direct Current.—If a 110-volt direct-current lighting circuit is available, the induction coil will

* *X*-ray tubes may be excited by other means than by the use of the three types of apparatus above mentioned, but these three are the only ones which have had any extended use.

undoubtedly be the best type of exciting apparatus to employ.

For the man who expects to use his apparatus occasionally for fluoroscopic examinations or easy radiographic work, an induction coil rated at 12- or 15-inch spark, and provided with a vibrating interrupter or a mercury turbine interrupter, will probably be satisfactory. Such an outfit is comparatively simple in operation, and is not very liable to get out of order.

For the same requirements a good static machine will answer perfectly well, and may be preferred by those who wish to employ the static machine for other purposes than *x*-ray work. If the static machine is preferred, the best kind to get will be a machine having eight to twelve revolving glass plates about 30 inches in diameter. With the static machine it will be necessary to get a small direct-current motor with a speed-controlling rheostat. For the smaller machine a one-sixth horse-power motor may suffice, but it will usually be found more satisfactory to use a motor rated at about one-fourth horse-power. It is well to leave the selection of the motor, the pulleys, and the rheostat to the maker or dealer from whom the static machine is purchased, but when doing this, a few dollars more expended for a motor of ample power will not be wasted.

If the space is limited, or if it is not desired to use electrical discharges for therapeutic and other purposes than *x*-ray work, it will be better to use an induction coil outfit.

For the man who intends to make a specialty of radiographic work a good induction coil provided with interrupters which produce with it very powerful discharges, is indispensable. This coil may be rated at 15-, 18-, 20-, or 30-inch spark length. It really does not matter much about the spark length if the energy of the discharge when the coil is delivering sparks about eight inches long is great enough. There are 30-inch coils which are unsuitable for the most difficult radiographic work, and there are coils rated at 10-inch spark length which, equipped with proper interrupters, will deliver more energy than any *x*-ray tube yet made can withstand for more than a few seconds. A coil giving this sort of a discharge is the one to be used.

It should be supplied with at least two interrupters: an electrolytic interrupter for the rapid exposures of from one to thirty seconds, and a good mechanical interrupter for the work requiring continuous operation. For this kind of work a vibrating interrupter may be used, but a rotary break or mercury turbine interrupter will probably be found more satisfactory. This induction coil and interrupter will be provided with a rheostat of large carrying capacity for controlling the strength of the current, and probably with an ammeter for measuring its strength, perhaps by a more or less elaborate switchboard with the controlling devices mounted on it.

Many of the successful Röntgen specialists in Germany employ enormous coils which are designed to deliver sparks one meter long. In the chapter on induction coil I have given a few of the reasons why such coils are not only unnecessary but undesirable for *x*-ray work. These statements seem justified by the fact that the excellent radiographs and the exceedingly short exposures that have been made with these large coils have been equalled, if not surpassed, by the use of an induction coil so small that it can be conveniently carried in a cab.

For the large hospital or public institution where a great amount of work of every variety is to be done, it will be found advantageous to have at least two complete *x*-ray outfits, and to arrange them so that they may be used at the same time for therapeutic purposes. If there are but two outfits, it will be convenient to have both a coil and a static machine. If a large number of outfits are needed for treatment, these would better be induction coils of about 8- to 10-inch spark length, with vibrating or mercury interrupters.

For Alternating-current Circuits.—When the only available source of current supply is an alternating electric light circuit, the selection of an equipment will be somewhat modified. For ordinary office use it will be possible to employ either static machine or induction coil of the sizes recommended for use with the direct current.

With a static machine it makes very little difference whether the power is derived from the alternating, or direct-current circuit, but with an induction coil the alternating current will

not give results so satisfactory as may be obtained with the direct current. If the matter of space is not to be considered, I should be inclined to prefer the static machine for these conditions. An alternating-current motor will be required instead of a direct-current motor, and since nearly all alternating-current motors run at a constant speed, a speed-regulating rheostat cannot be used, and it will be necessary to regulate the output of the machine by varying its speed independently of the motor. This may be accomplished either by cone pulleys giving two or three speeds, or by the friction device mentioned in Chapter IV. There is really not much necessity for accurate regulation of the speed of the static machine, and I think that the cone pulleys are preferable. They are simpler, cheaper, and less likely to give trouble.

The induction coil may be operated from an alternating-current circuit in several ways that have been mentioned in Chapter III. For the purpose of *x*-ray treatments, probably the best plan is to use a mercury turbine interrupter with synchronous motor shown in figure 33. This arrangement will also give fairly good results for fluoroscopic examinations and for radiographing the extremities. It can be operated continuously without trouble, and for the average user will probably give satisfactory results. For the purposes of *x*-ray treatment a coil operated by the liquid interrupter shown in figure 38 may be used with double focus tubes. This arrangement will not be so satisfactory for fluoroscopic examinations, and for continuous operation it will be necessary to use two or three interrupters and to change from one to the other at intervals of ten to twenty minutes.

For fluoroscopic and radiographic work the best method of operating an induction coil directly from the alternating current will be to use the Wehnelt interrupter and single focus tube. Because of the wearing away of the platinum this interrupter will require more attention than the liquid interrupter mentioned above, and for continuous operation it will be necessary, as before, to use more than one interrupter.

Various electrolytic valves for suppressing one wave of the alternating current, and thus allowing the current to flow in

waves of one direction only, have been devised. It has been suggested to use them in connection with ordinary interrupters for operating induction coils from alternating-current circuit. These devices absorb considerable energy, they all require more or less attention, and they deteriorate rapidly.

For the man who makes a specialty of radiographic work and who has only the alternating current source of supply available the best plan will be to employ a powerful induction coil and operate it with a Wehnelt interrupter of the type shown in figure 37. In his work the exposures will be short, and the wearing away of the platinum will not be of so much consequence as when the apparatus is used for treatments in which the exposures extend over ten to fifteen minutes. At present there is no method of operating induction coils directly from the alternating-current circuit which will give as satisfactory results in radiographic work as may be obtained with the direct current. However, several operators have obtained beautiful radiographs of the thorax with exposures of from twenty to sixty seconds by using the arrangement just mentioned. If much work is to be done it will, of course, be advisable to have several electrolytic interrupters. For continuous operation of the coil such as would be needed in making fluoroscopic examinations, the mercury turbine interrupters with synchronous motor will be very useful.

Hospital equipments for use with the alternating current will not differ materially from those just described.

When no Lighting or Power Circuit is Available.—When this is the case, the static machine may be operated by hand-power, water-moter, by power from shafting, by a gas-engine, etc. Nearly all of these methods will be found more or less inconvenient and troublesome. If a high pressure water-supply is available, a water motor will be very satisfactory for this purpose. If an induction coil is used, it may be operated either from primary batteries or from storage batteries. The best plan is to use an induction coil and operate it from a storage battery. If there is a power station near by, where batteries may be recharged, it is a good idea to have two sets of storage

batteries, so that one may be used while the other is being recharged.

In certain isolated cases it may be advisable to install a gas-engine and dynamo for operating the coil, but this is a matter which should be left to a competent electrical engineer. Such outfits are of standard manufacture for isolated electric lighting plants. They are rather expensive, and gas- or oil-engines are more or less troublesome.

Excellent radiographs of every part of the body may be obtained by employing a coil operated from a storage battery, but it will be necessary to make longer exposures than would be needed when the coil is operated from an electric lighting or power circuit. For use with a storage battery it is advisable to have a coil somewhat larger than would be necessary for use with the electric lighting circuit. A vibrating interrupter or a mercury dip interrupter will be best for use with the storage battery.

Selection of Tubes.—For the use with static machines, tubes of the type shown in figures 7, 8, and 9 will be found most satisfactory and reliable. They are cheaper than the more complicated forms with regulators, and with a static machine it is better to have a large number of these tubes of different degrees of exhaustion than to attempt to secure different degrees of penetration from the same tube by means of a vacuum regulator.

For treatment, for fluoroscopic work, and for the easier radiographic work, tubes of the same types will be found very satisfactory for use with the induction coil.

For the most rapid radiographic work with the induction coil and electrolytic interrupter, it will be necessary to use tubes with strong, well-made targets which enable them to withstand heavy discharges. Tubes with very heavy platinum targets faced with iridium are probably as good as any, but they are expensive and difficult to obtain, and, moreover, it is quite difficult to regulate the vacuum of such a tube.

Of the types on the market, the water-cooled tubes, such as the one shown in figure 17, and the heavy target tubes, such as are shown in figures 12, 13, 14, and 18, are probably the

best for this purpose. For use with induction coils, regulating tubes are generally preferred to the non-regulating tubes, except when comparatively weak discharges are employed, such as are used in *x*-ray treatment. The addition of the regulator increases the useful life of the tube, and although none of them are entirely satisfactory, they do give some control of the vacuum.

Accessory Appliances.—While the exciting apparatus and tubes are the most essential parts of an *x*-ray equipment, they form but a small part of it. A number of auxiliary devices, such as tube-holders, plate-holders, fluoroscopes, numbering devices, localizing apparatus, etc., will be needed. The choice of these will be determined by the character of the work which one intends to do.

The merits of these accessories have been discussed in the chapters on Fluoroscopy and Radiography.

PART II

THE THERAPEUTIC APPLICATION OF X-RAYS.

BY

WILLIAM ALLEN PUSEY, M.D.

PREFACE.

During the last three years an extensive literature has sprung up upon the subject of the therapeutic application of *x*-rays, and the present seems an opportune time to make a critical review of this literature. I have undertaken in the following pages to consider as carefully as I am able the authentic literature which has developed upon this subject, and I have supplemented that by as full a review of my own experience in this field as the subject seemed to warrant. I have given as fully as possible the details of my own experience and of the experience of other workers, for it is only by the accumulation of such data that it becomes possible to arrive at a satisfactory estimate of the value of the method.

The aim has been particularly to elucidate fully the practical aspects of the subject, so that the reader can get definite information upon the various practical points that go to make up a satisfactory working knowledge of the subject.

The subject of *x*-ray therapeutics is of course in a stage of development; it is in a comparatively early stage of development, but data are not lacking even at the present time to allow us to obtain a not unsatisfactory grasp of the limitations and possibilities of the method. In order to arrive at satisfactory conclusions upon these questions, what we must have is facts; and the aim in these pages has been to record the facts. That done, the reader is in position to attach to them the weight to which in his opinion they are entitled. The only claim that I would make is that it has been my constant endeavor to keep well within the facts.

Wm. Allen Pusey.

Chicago, April, 1903.

CHAPTER I.

THE EFFECTS OF X-RAYS ON TISSUES.

THE use of *x*-rays for therapeutic purposes presents a problem entirely different from that which confronts us in the use of the same agent as a means of diagnosis. On the one hand, the ideal condition is to get a satisfactory image without in any way affecting the tissues; on the other, we are directly and solely concerned with the effect upon living tissues. In the use of *x*-rays for therapeutic purposes we must utilize those very qualities of the agent which we strive to escape in diagnostic work; we must produce effects upon the tissues, and we must so regulate these effects that they may be utilized without overstepping the bounds of safety. It goes without saying that the utilization of the effect of *x*-rays on tissues presents a nice problem in the regulation of an agent whose control is extremely difficult, and that for any successful solution of this problem as complete a knowledge as possible of the effect of *x*-rays upon living tissues is of fundamental importance. As a preliminary, therefore, to the application of *x*-rays to therapeutic purposes we must consider fully their effects upon living tissues. Fortunately our knowledge upon this subject, thanks to the studies of numerous observers, is by no means so limited as is generally supposed.

Gross Effects upon Tissues.—The effects of *x*-rays upon tissues have been studied almost exclusively as they occur in the skin, for the very obvious reason that the skin, which bears the brunt of the exposures, is the part which always shows the most marked *x*-ray effects. When the surface of the body is exposed to *x*-rays to a sufficient extent to produce a reaction,* very definite results occur. The first effect to be

* Various names have been used to describe the reaction produced in tissues by *x*-rays. The term burn was first applied, but vigorous objections have been raised against its use, chiefly on the ground that the injury produced by *x*-rays

seen is either slight pigmentation, slight erythema, blanching of the hairs, or loosening of the hairs. These changes usually develop in the above order, but any one of them may come first. Pigmentation may occur without redness; again, the pigmentation may be very slight, or not occur, or be completely overshadowed by the redness. Loosening of the hairs frequently occurs without blanching, but I have not seen the reverse happen. Neither of these latter changes occurs without accompanying pigmentation or erythema.

Pigmentation.—The effect that shows itself first in perhaps most cases is pigmentation. This is likely to be quickly followed by blanching or loosening of the hairs, particularly dark hairs, and then by the development of redness. This pigmentation of the skin from moderate *x*-ray influence differs in no apparent respect from that produced by exposures to sunlight. It is a superficial deposit of pigment, and is unquestionably, in my opinion, a result of the same process that causes tanning from exposure to sunlight. The amount of this deposit of pigment varies considerably according to the susceptibility of the individual and the intensity of the *x*-ray exposure. In many cases it amounts only to a slight tanning; in certain others after long-continued exposure the skin becomes a dark brown. At times on surfaces exposed to moderate *x*-ray influence there develop freckles indistinguishable from the ordinary lentigines produced by sunlight. This freckling is sometimes a precursor by several days of diffuse pigmentation, but such diffuse pigmentation is by no means usually associated with any preliminary appearance of freckles. The

does not entirely correspond to a heat burn. To my mind the objection is not particularly valid. Burn is by no means confined in its application to the reaction produced by heat. It is applied to injuries produced by sunlight and other forms of light, by electricity, and by chemicals, all of which have peculiarities. It is, of course, true that the injuries produced by *x*-rays are not identical with those produced by heat, but they are processes which suggest very closely heat burns and other injuries to which the term burn is applied. As a matter of fact, burn describes the condition more closely than any other term that we have. And as burn has long since ceased to be confined in its application to heat burns, but is applied to various similar processes without predicating anything as to their causation, it seems an excess of purism to deny the use of the word to the injuries produced by *x*-rays.

appearance of freckles occurs in individuals who show the same phenomenon under exposure to sunlight. Ordinarily the individual who shows the greatest amount of pigmentation from *x*-ray exposure is the one who normally has a large amount of pigment in the skin. The reaction of different individuals in respect to the deposit of pigment is very similar to their reaction to sunlight. Skins which burn rather than tan under sunlight develop erythema rather than pigmentation under *x*-rays, and skins which tan without burning under sunlight show relatively the same reaction under *x*-rays. Indeed the entire reaction produced by *x*-ray irritation, whether tanning or burning, is practically identical with that produced by sunlight.

Dermatitis.—The inflammatory effects produced by *x*-rays upon tissues may be divided into four classes, corresponding to the four degrees of heat burns ordinarily described. In burns of the first degree there is a dry dermatitis with erythema without destruction of tissue; in burns of the second degree, dermatitis with the formation of vesicles and blebs but without deeper involvement; in burns of the third degree, destruction of the epidermis; in burns of the fourth degree the destruction involves not only the entire epidermis, but the corium as well, and also the underlying tissue to a greater or less extent. The dermatitis produced by *x*-rays appears first around the follicles as punctate redness, which immediately develops into a diffuse pinkish erythema over the involved area. This is likely to be accompanied by some tingling or burning. The process may stop at this point. If so, prompt subsidence of irritation usually occurs, accompanied by slight desquamation, after which there is left more or less pigmentation, depending upon the pigment-forming characteristics of the particular skin. If the process goes beyond this first erythema, there may develop a lively red dermatitis which is at first dry but is likely to go on to vesiculation. The process may stop at vesiculation; if so, the vesicles rupture and there is left a slightly weeping surface which is usually rapidly covered by a layer of grayish horny epithelium, and the process undergoes prompt involution from this point. The subjective sensations

accompanying this type of burn do not differ materially from those of a similar degree of dermatitis from other causes.

If the *x*-ray irritation goes beyond the stage just described, instead of stopping at the development of a lively red dermatitis with vesiculation, the surface becomes a dark angry red. The congestion in this condition is intense; the redness disappears on pressure but instantly returns; vesicles and bullæ form upon the surface, rupture, and leave a congested, weeping surface. There then develops upon this raw surface a thin yellowish-gray necrotic membrane. This is closely adherent and its forcible removal is followed by very free bleeding. This necrotic membrane is made up solely of epithelium. One is apt to believe that it involves the connective tissue, but in the particular degree of *x*-ray burn now under consideration this is not the case. With burns of this degree there is likely to be considerable swelling the connective tissue. The accompanying subjective sensa- vary very much in individuals; some patients complain little or not at all, but in most of them there is very decided ing or itching. In some cases the itching is very intense rsists for a comparatively long time. Some patients com- of pain, but the pain is never of the severe character d in *x*-ray burns with destruction of connective tissue.

The course of burns which reach this point of irritation varies. Some of them recover rapidly; the necrotic membrane is promptly thrown off, horny epidermis grows rapidly around the borders, islands of horny epidermis spring up at various points in the affected area, and in the course of three or four weeks from the time of the appearance of the bullæ the area is again covered with horny epidermis. Other cases do not recover so pidly. The formation of epidermis is slower, and at times recovery will be retarded by vesicles and bullæ reappearing, haps again and again, after a new layer of horny epidermis formed. In such a case, when relapses occur, the surface is or less covered with grayish horny epidermis, interspersed many weeping patches. With these relapses the irritation e continued for several months, but usually in the course r four months relapses cease, and the surface becomes h permanent horny epidermis. Redness may persist

for many weeks, but there is, as a rule, not much pigmentation. The epithelium formed over the surface is smooth and thin, and the entire absence of hair and follicles gives the skin a smooth but not disfiguring appearance. This new skin is for some time quite sensitive to external irritants. Finally, however, the usual tolerance develops.

After-effects on the Skin.—After *x*-ray irritation of all of the degrees above described, the skin presents a slightly atrophic appearance. It is softer and a little thinner than normal and is liable to show a slight cigarette-paper appearance with exaggeration of the normal lines. If the exposures have been over the face, the wrinkling of the skin at the corners of the mouth may be sufficient to attract the patient's attention. This atrophy of the skin is most pronounced immediately after the disappearance of the redness, and gradually disappears in most cases. These atrophic changes are seen at times in cases in which the dermatitis has been almost *nil*, but in which there has been a continued moderate *x*-ray effect sufficient to cause pigmentation and destruction of the follicles.

Burns Involving the Subcutaneous Tissue.—In burns of the fourth degree the evolution up to the point of congestion and vesiculation is the same as that described above for burns of lesser severity, but the process does not stop at that point. The congestion goes on until the surface is almost cyanotic, the skin becomes brawny and tense, bullæ develop, and these are followed by necrosis of the underlying tissue (Fig. 92). The resulting lesion is practically unique. There develops a hard, leathery, dark-grayish mass of mummified tissue, which is closely adherent and is surrounded by an indurated, inflamed periphery. Its dry, mummified appearance, its leathery consistency, and its "almost malignant tendency to persist," place it in marked contrast with any other similar lesion. The line of demarcation between the living and dead tissue of these lesions is not well established. Butler * has observed that occasionally tissue that is black and apparently dead, when cut bleeds and causes great pain; and Cassidy † in the excision

* American Practitioner and News, 1900, xxix, p. 361.

† Medical Record, 1900, lvii, p. 180.

of such a slough found that to get all of the diseased tissue he had to carry his incision two inches outside of what appeared on the surface to be the line of demarcation. These masses of apparently dead tissue, if they are not removed by surgical means, are likely to persist for a long time. Usually they are not thrown off for several months, and their persistence may extend to a year or more. The surrounding tissues, however, in time begin to regain their tone, the borders of the ulcers gradually contract and the necrotic mass disappears, and finally scar tissue takes its place.

Extent of Burns. Pain. Scars.—The depth to which the tissues are involved in burns of this degree is limited only by the intensity of the *x*-ray effects. In Cassidy's case the injury involved the tissues of the thigh to the depth of an inch and a half, surrounding but not affecting the femoral artery. In a case for a description of which I am indebted to Dr. E. Wyllys Andrews, the burn "included the whole external ear, the right eyelids and eyeball, and the outer table of the skull, in the parietal region." The superficial extent is limited only by the extent of the exposure. In a case seen by Dr. L. L. McArthur "the burn began at chin and ended at symphysis, and extended from right axillary line to left mammary. . . . . The gangrenous area was about nine inches long by six wide when I operated some three months, I think, after the exposure."

The pain accompanying these lesions is of the most varying intensity. Rarely it is not severe. In the great majority of cases it is extreme. It is described at times as dull boring pain, again as sharp lancinating pain, again as burning, "as if red-hot coals were applied to the part." The scars left after these ulcers are similar to the scars after other ulcers of the same extent, with the exception that they are apt to be more vascular. Sequeira * has reported a case in which there remained in the scar numerous telangiectases, and Wylie † has reported a case, probably of similar character, in which there persisted three months after the healing of the ulcer scarlet rings the size of a half-dollar, apparently permanent.

* Brit. Jour. of Derm., 1902, xiv, p. 19.

† Brit. Med. Jour., 1901, i, p. 338.

Fig. 92.—X-ray burn of the fourth degree, of eight months' duration.

Chronic X-ray Dermatitis.—There is a fifth form of *x*-ray injury which is seen in *x*-ray workers who are exposed more or less to the influence of the rays over a long period of time. It occurs almost exclusively on the hands, by reason of their greater exposure, and presents itself as a persistent atrophic dermatitis. The skin of the affected areas, usually the backs of the hands, becomes atrophic and thin, and crackled like parchment. It may be smooth and glassy in appearance, with entire absence of the follicular openings and hairs, and with a tendency to crack about the joints. The skin is pinkish-white, mottled with small reddish vascular patches, and with decided redness about the knuckles. Codman * describes this condition as follows: "In the less pronounced forms the skin appears chapped and roughened, and the normal markings are destroyed; at the knuckles the folds of skin are swollen and stiff, while between there is a peculiar dotting resembling small capillary hemorrhages. The nutrition of the nails is affected so that the longitudinal striations become marked and the substance becomes brittle. If the process is more severe, there is a formation of blebs, exfoliation of epidermis, and loss of the nails. In the worst form the skin is entirely destroyed in places, the nails do not reappear and the tendons and joints are damaged."

Hyperkeratosis.—While the condition in these chronic forms of *x*-ray irritation is as a whole atrophic, there is at times a peculiar tendency to hyperkeratosis which shows itself in increased horniness of the epidermis about the knuckles and in the formation of keratotic patches. In some cases this is very marked, so that the affected parts, usually the backs of the hands, have scattered over them many keratoses with or without inflamed bases. The appearance is very similar to that seen in cases of senile keratosis where the patches are inflamed and have a tendency to epitheliomatous degeneration. In one case that I have seen, in which the face, the arms, the hands, and the front and back of the chest were involved in a chronic *x*-ray dermatitis, the atrophic dry skin, the very deep freckling, the numerous hyperkeratoses, and

* Phila. Med. Jour., 1902, ix, 438.

the telangiectases made a picture strikingly like that of an early stage of xeroderma pigmentosum. Indeed in some of the cases this resemblance to senile keratosis with a predisposition to epitheliomatous degeneration has been so marked that I believe there is a possibility of epitheliomata developing on these bases.

The above was written before I knew of any other observation upon this point. Johnston,* however, has called attention to this keratosis as "precancerous keratosis." He believes that these patches are likely to become epitheliomata, and gives a report of the case of a surgeon who used *x*-rays extensively, on the backs of whose hands about twenty keratoses developed. Two of the largest were excised and examined microscopically, the first showing only subacute inflammation in the cutis, with lymphocytosis and some proliferated fibroblasts. The second, however, in his opinion showed unmistakable evidences of malignancy in the form of numerous mitoses and rupture of epithelium into the corium. In an as yet unpublished discussion before the American Dermatological Association, Boston, September, 1902, Dr. C. W. Allen reported a case of epithelioma which developed in the cicatrix of an *x*-ray burn on the back of the wrist, and for which amputation of the forearm was done, and Dr. J. C. White referred to an epithelioma which had developed in an *x*-ray burn. This condition of hyperkeratosis from chronic *x*-ray irritation is therefore one of serious importance, and its dangerous possibilities should be borne in mind. It is probable in my opinion that many cases of epithelioma will be found to develop upon the backs of the hands of *x*-ray workers who have a persistent, chronic inflammatory process with hyperkeratosis, as a result of continued exposures to *x*-rays.

Changes in the Appendages.—The reference to the nails in the quotation from Codman above describes very well the changes which occur in the nails in all types of *x*-ray burns. Evidences of marked nutritional disturbances in the nails appear early, for the nails, like the other appendages of the skin, show a marked susceptibility to the influence of *x*-rays. The changes

* Phila. Med. Jour., 1902, ix, p. 220.

in the nails vary from slight linear striation to the production of a mere rudimentary nail, or the absence of the nails entirely. The changes in the other appendages have been already briefly referred to above. In all degrees of *x*-ray irritation the hairs are affected. Outfall of the hairs occurs with or without previous blanching. In severe *x*-ray burns the burn usually develops before the hairs fall out. When the surface has become brawny and cyanotic, the hairs may still remain, but they come out without force, as after a scald.

Deep-seated X-ray Effects.—Several cases have been reported of internal lesion due to *x*-rays without corresponding effect upon the overlying tissue. N. Stone Scott,* in a review of *x*-ray injuries, has considered all these cases. Among the cases of *x*-ray injuries that he was able to find there were but six which could possibly be classed as primary internal injuries, and in none of these is the evidence conclusive. The case to which the greatest attention has been given is Gilchrist's † case of *x*-ray dermatitis of the hand with supposed osteoplastic periostitis of the bones of the hand. Scott considers this case at length, and concludes, correctly in my opinion, that the periosteal lesion is not demonstrated, and that Gilchrist's conclusion that there was a thickening of the bones of the hand is an incorrect interpretation of the pictures. It is, I believe, *a priori* highly improbable that primary deep-seated *x*-ray effects can be produced upon normal tissue without more intense effect being produced in the overlying tissue, and there are no cases on record that tend to weaken this theoretical position.

This is an entirely different matter from the statement that effects are not produced upon deeper tissues. There is every reason to believe that *x*-rays may affect deep-seated tissue, but this effect must be less than that upon the tissues nearer the source of the *x*-rays. Every theoretical consideration indicates that the effect of *x*-rays on the deep tissues is relatively less than upon the overlying tissues. The *x*-rays of course penetrate the deeper tissues, even to the point of going entirely

* Transactions Ohio Medical Society, 1897, lii, p. 139.
† Johns Hopkins Hosp. Bull., 1897, viii, p. 17.

through the body, and certain of the rays are absorbed by every tissue through which they pass.

In cases which I have had under treatment for various pathological conditions the results leave no room for doubt that *x*-rays produced definite effects upon deep-seated tissues. In a case of recurrent carcinoma of the breast with involvement of the axilla, and enormous œdema of the arm (Case 75), not only all evidence of carcinoma disappeared, but also very great œdema. In a second case of carcinoma of the breast (Case 97) the findings are even more definite. This was a case of primary carcinoma of the breast with involvement of the axilla and with metastases in the spine and in the chest, when treatment was begun. The exposures were given only over the breast and axilla. The patient died three months after the beginning of treatment. In the mean time an acute dermatitis had been produced on at least two occasions. At the postmortem, held by Dr. J. J. Larkin, of Chicago, it was found that "the tumor of the breast had nearly all disappeared" and "the enlarged glands under the arm on affected side had reduced to one-third of their former size." Similar deep-seated effects of the rays are to be seen in a case of sarcoma (Case 128), and in Case 149, of pseudo-leukemia. In all of these cases the lesions reached nearly to the surface, but they extended certainly to a depth of several inches, and the results leave no room for doubt that the deepest tissue was affected as well as that nearer the surface.

Rollins * has performed experiments upon guinea-pigs which are interesting in this connection. He exposed two strong guinea-pigs two hours a day to *x*-rays. One died in eleven days, the other in eight days. In a pregnant female guinea-pig exposed under similar circumstances the fetus was killed. Elihu Thomson,† in a similar experiment, exposed a healthy mouse for one hour to powerful *x*-rays, with the result that it died the next day. Oudin, Barthélemy and Darier ‡ have reported two cases of vomiting in children, following *x*-ray

* Boston Med. and Surg. Jour., 1901, cxliv, pp. 173, 317.

† American X-ray Journal, 1898, iii, p. 451.

‡ Monatshefte f. prakt. Derm., 1897, xxv, p. 417.

exposures, which are possibly attributable to the effect of the *x*-rays. They also report a man who developed an acute miliary tuberculosis while taking *x*-ray exposures, and who suffered much from palpitation and pain in the heart, which he attributed to the *x*-rays. In none of these cases is the evidence of the effect conclusive. Walsh* has reported two cases suggesting deep-seated effects of *x*-rays. In one case the patient suffered from cerebral symptoms suggestive of sunstroke. He had been in the habit of demonstrating the *x*-rays and had had repeated and prolonged exposures. He had from time to time dermatitis, and later developed headache, vertigo, vomiting, dimness of sight, and great prostration. The symptoms were said to be practically those of sunstroke. He stopped the exposures and went to the seaside, and the symptoms disappeared. In the second case an *x*-ray worker gave his abdomen long exposures repeatedly. After some weeks he complained of abdominal symptoms, pain, tenderness, flatulency, diarrhea. On removing to the country these symptoms disappeared, but returned upon renewing the work. He then shielded his abdomen with sheet-lead, and the symptoms finally disappeared. Another evidence of the deep-seated effect of *x*-rays is found in the relief of pain due to deep-seated pathological processes. This anodyne effect of *x*-rays is unmistakably manifest in various deep-seated pathological processes subjected to *x*-ray exposures.

Scholtz† is inclined to doubt the possibility of such deep-seated effects, and intimates that they may be due to suggestion. This hardly seems to cover the situation. The writers who have reported these cases are careful, trained observers, not likely to be misled; and, in addition, the occurrences are by no means impossible. The fact of the relief of deep-seated pain by *x*-rays is sufficient to indicate the possibility of *x*-rays producing an impression upon deep-seated tissues; and as to this relief at times of deep-seated pain by *x*-rays there can be no manner of doubt. This has happened frequently in

* "The Röntgen Rays in Medical Work," Wm. Wood Co., N. Y., 1902, pp. 205, 206.

† Arch. f. Derm. u. Syph., 1902, lix, p. 87.

my experience, and under conditions where the possibility of suggestion and other factors could be ruled out. Other symptoms, as vomiting, vertigo, and prostration, I have not observed, although I have had considerable experience with *x*-ray burns in locations where such symptoms might have been expected. This matter of deep-seated *x*-ray effect is of the utmost importance. If it could be demonstrated that as great effect can be produced by *x*-rays upon deep tissues as is produced upon the tissues overlying them, it would be of course of the highest significance in the question of treatment with *x*-rays of deep-seated pathological conditions. Unfortunately it is surely true that the effect upon deeper tissues can never be as great as upon those overlying them. The quantity of *x*-rays that reaches a given surface is inversely as the square of the distance; in addition, a certain quantity of *x*-rays must be absorbed by every overlying tissue, so that for both of these reasons it is impossible that as great effect should be produced in deep-seated tissues as in those that cover them.

Time of First Appearance of Symptoms.—The time of the first evidence of *x*-ray effects upon the tissues varies from the appearance of symptoms at the time of exposure or a few hours later to several weeks thereafter. In a few cases it is recorded that evidence of irritation showed itself at the time of exposure. In a case reported by Fuchs * vesicles developed fifteen minutes after exposure. In the vast majority of cases, however, the first appearance is from three to fifteen days after exposure. Upon this point Codman,† in a very thoughtful critical review of *x*-ray injuries, which comprehends all recorded cases, makes the following statement:

"The impression has prevailed that these lesions usually make their first appearance only after a number of days. The following is a table of the records as to this point:

* Deutsch. med. Wochenschr., 1896, xxii, p. 569.

† Phila. Med. Jour., 1902, ix, pp. 438 and 499.

In	9	instances	signs	or	symptoms	were	noticed	within 24 hours
"	6	"	"	"	"	"	"	" 2 days
"	6	"	"	"	"	"	"	" 3 days
"	2	"	"	"	"	"	"	" 4 days
"	5	"	"	"	"	"	"	" 5 days
"	3	"	"	"	"	"	"	" 6 days
"	3	"	"	"	"	"	"	" 7 days
"	4	"	"	"	"	"	"	" 8 days
"	2	"	"	"	"	"	"	" 9 days
"	9	"	"	"	"	"	"	" 10 days
"	8	"	"	"	"	"	"	" 10–14 days
"	8	"	"	"	"	"	"	" 15–21 days
"	2	"	"	"	"	"	"	" 22–28 days
"	3	"	"	"	"	"	"	after the fourth week
	70							

These figures indicate that at least in a good proportion of the cases the first symptoms are noticed within the first few days after the exposure. Three are mentioned as being noticed immediately after the exposure. It seems possible that the reason that so many are first noticed in the second and third weeks is that it is at this time that the sensitiveness of the lesion becomes severe enough to attract the attention of the patient. In some cases, however, this late appearance is well substantiated; *e. g.*, in the cases of Thomson, Orleman, and Barthélemy. But five cases of my series—Cases 3, 4, 41, 126, and 147—appeared later than twenty-one days. It is unfortunate that we have not more accurate reports of them."

Other studies upon this point give practically the same findings, as will be seen, for example, by reference to the tables of Gilchrist * and Scott.† In a personal experience covering several hundred cases I have never seen a reaction occur as late as three weeks after exposure. In the 171 cases of *x*-ray burns which Codman is able to find, he states that five of these, and but five, developed later than twenty-one days after exposure. I am able to find, however, on analysis of his cases, only three that developed more than twenty-one days after exposure. Of these, two cases, Dale's and Scott's, are given as developing four weeks after exposure, and one, Stinson's, between three and six weeks after exposure. In Dale's case

* Johns Hopkins Hosp. Bull., 1897, viii, p. 17.

† Trans. Ohio State Med. Society, 1897, lii, p. 139.

was a moist dermatitis, which appeared twenty-eight ter exposure, and lasted for a short time. Stone Scott's is a personal report to Codman of an unpublished case, time of the development was given as four weeks. nson's case a fracture was exposed to *x*-rays, and three later a plaster cast was applied. Six weeks later there was a purulent dermatitis under the plaster. It is apparently not excluded in this case that the dermatitis was not a dermatitis such as is often seen under plaster casts. Barthélemy's case, which is given as a case with the development of an *x*-ray injury five months after exposure, on examination shows that the primary skin effect was by no means so late. The patient had several *x*-ray exposures, which produced no reddening of the skin, but did cause pigmentation, followed by slight desquamation at the end of treatment. Five months later an irritated patch developed, with hypervascularization and redness and desquamation. The lesion occurring five months after exposure, therefore, was not the first *x*-ray effect on the skin. That there was an inflammatory process at the time of the pigmentation is shown by the subsequent desquamation. His case, accordingly, should be included in the class of cases in which there has been a relapse of dermatitis some time after the original irritation, two examples of which I have reported on pages 342 and 344.

When one takes into consideration the chances of error as regards time of development of these burns, it will be seen that the evidence in favor of the development of *x*-ray injuries more than three weeks after date of exposure is not very strong. Only three cases are to be found. In none of these is the evidence conclusive, and in none except Stone Scott's, in which there is said to have been "dermatitis with ulceration," was the injury at all serious. It appears on the whole, therefore, that it may be stated with reasonable accuracy that the development of *x*-ray burns is practically always within three weeks after the last exposure.

Duration of X-ray Burns.—There is a paucity of data in the literature concerning the duration of *x*-ray effects, except in severe burns with necrosis. My own experience on this

subject covers a very considerable number of cases of slighter degrees of *x*-ray burns, from which fairly accurate data may be gotten. Pigmentation produced by *x*-rays disappears slowly. In some cases, even where the tanning was considerable, I have seen it disappear in two to six weeks. In a few other cases, not more severe, traces of pigmentation have lasted for eight months before finally disappearing. The difference here is probably simply one in the pigment-forming characteristics of the individual skins. The period that elapses between the time that hairs disappear and return varies very greatly. In certain cases I have seen the hairs begin to return within four weeks after their disappearance. In other cases six to twelve weeks or longer may elapse before there is evidence of regeneration of the hair follicles, and in some cases return of hair does not occur after their first outfall from *x*-ray exposures.

In *x*-ray dermatitis the duration of the process depends partly upon the intensity of the burn, but more upon individual susceptibility. A phenomenon that is sometimes witnessed in cases that are being exposed from day to day to *x*-rays is the development of a very slight erythema after exposure and its disappearance before the exposure of the next day. This is a condition that sometimes precedes the development of the ordinary dermatitis. In cases of moderate dermatitis without vesiculation the process usually increases for five or six days, then remains stationary for a few days, and then undergoes rapid involution, the whole cycle taking ten to twenty days. In one case of dermatitis of the first degree of which I have notes the effect increased slightly for four days after its appearance, and disappeared entirely by the end of eight days. In another case by the end of four days from its appearance there was a rather lively red, acute, dry dermatitis, which remained unchanged for two days and then rapidly subsided, until on the tenth day the surface was entirely restored to normal except for a slight pigmentation. In dermatitis of the second and third degrees the process as I have seen it reaches its climax in one to two weeks. For example, in one case of acute dermatitis with moderate vesiculation,

seven days after slight erythema was noticed the process reached its most acute stage, by the end of fifteen days it was manifestly subsiding, and at the end of twenty-one days was entirely gone. In another case, in which the dermatitis became quite acute, there was on the eighth day after the first trace was noticed an acutely inflamed red surface covered with vesicles. By the tenth day these had ruptured and a necrotic pellicle had formed and covered the whole of the raw surface. By the twelfth day the line of demarcation of this necrotic membrane was sharply defined. This remained stationary until the fifteenth day. From the fifteenth day there was gradual contraction of its margins, and at the end of forty days the surface was entirely covered with healthy epidermis. In another case, a little more severe that the preceding, four days after the last exposure slight erythema with sensation of heat was noticed. On the tenth day from the last exposure the surface was congested, dark red, and angry looking. On the fourteenth day it was covered with vesicles. On the sixteenth day there was a necrotic membrane over a space three inches square, and one day later the line of demarcation of this membrane was well marked. The condition remained stationary for about five days, or until the twenty-second day, after which it gradually contracted, until on the forty-second day the surface was entirely covered with healthy epidermis with just a trace of redness left.

Relapses.—In three rather severe cases of dermatitis, each accompanied by the formation of a superficial necrotic membrane, relapses occurred in each case approximately two months after the disappearance of the first dermatitis. In one of these cases there was a second relapse six months after the first dermatitis. In none of these cases was the relapse so acute as the first attack. In two of the cases the recurrence was indistinguishable from a vesicular eczema. Indeed it is not established that the apparent relapse was not a dermatitis from external irritation in a surface of the skin whose normal tolerance had not yet been reestablished. In both of these cases eczema developed symmetrically on other parts of the body. In the third case, however, the recurrence was unques-

tionably an *x*-ray dermatitis of a character similar to but milder than the first attack. This case showed the recurrence at the end of two months. There was considerable congestion of the area, which was covered with gray horny epidermis with numerous weeping patches. This was a case of epithelioma treated by *x*-rays, in which before any effect was produced upon the lesion the effect upon the skin had to be carried to an extreme point.

As to the duration of burns with necrosis of the connective tissue, it is well known that they last for a very long time—from one or two months to a year or more, depending largely upon the severity of the burn. A case of carcinoma exposed to *x*-rays, which I have reported (Case 119), is interesting in connection with this question of the duration of *x*-ray effects upon the tissues. In this case the carcinoma involved the entire orbit. Exposures were continued for two months, with the production of a very acute dermatitis, but without any apparent effect upon the growth. Treatment was thereupon discontinued, but in spite of the fact that the patient had no further exposures the tumor continued to shrink for five months, and until it had almost entirely disappeared. A consideration of this question leaves no room for doubt that persistence is a marked characteristic of the reaction produced by *x*-rays on tissues. This quality has proved most troublesome in accidental *x*-ray burns. It must be reckoned with, and it may be used to good advantage in the therapeutic application of *x*-rays.

Cumulative Effects.—It is a necessary corollary of the foregoing that the effects of *x*-rays are cumulative when the sittings are often repeated. For, since there is a period of incubation lasting several days, and since the effects themselves continue for many days, it follows necessarily that exposures repeated during either of these periods must increase the effect upon the tissues. This cumulative action of repeated *x*-ray exposures is practically universally accepted and needs no extended discussion. It must be taken carefully into consideration in any attempt to give repeated exposures.

Idiosyncrasies.—According to almost universal opinion there

is a marked difference in the way in which tissues of different individuals react to the influence of *x*-rays. The only radical exception to this opinion that I know of is that of Kienböck,* who takes the position that "we are not justified in assuming an idiosyncrasy to *x*-rays." † He goes even further, and states ‡: "A fact of the greatest importance, from a therapeutic standpoint, is the knowledge that individuals in good health react in precisely a similar manner to *x*-ray radiance." And he builds an *x*-ray technique around this theory. In my judgment there is not the slightest suspicion of evidence to justify such a statement. The very fact that *x*-ray burns are comparatively so few demonstrates in the largest and most convincing way the inaccuracy of such a position. It is literally true that at the present time millions of *x*-ray exposures have been made, and most cases of burn of a severe character come to light; yet Codman in considering the subject of *x*-ray injuries is able to find recorded in all the literature only 170 burns. Gilchrist,§ in reviewing the literature in February, 1897, was able to collect only 23 cases, and Stone Scott,‖ in reviewing the subject in May, 1897, was able to find only 69 cases. With the hundreds of thousands of *x*-ray exposures that have been made, is it to be supposed that only 170 cases have been exposed beyond the point of safety? Or even suppose that only one in ten cases of severe burn has come to light, is it to be supposed that only 1700 cases of over-exposure have taken place? The supposition is an absurdity on the face of it. Probably in one month, three or four months after Röntgen's discovery was announced, over seventeen hundred cases were exposed in a way that we now know to be dangerous. Many cases of burn have unquestionably been caused by dangerous exposures; on the other hand, it is certainly true that thousands of what are dangerous exposures for some individuals have been made without injury. And the fact that in innumerable

* Wiener klin. Wochenschr., 1900, xiii, p. 1153; Wiener med. Presse, 1901, xlii, p. 873.

† Interstate Medical Journal, 1902, ix, pp. 1, 60. ‡ Ibid.

§ Johns Hopkins Hosp. Bull., 1897, viii, p. 17.

‖ Trans. Ohio State Med. Society, 1897, lii, p. 139.

cases the individuals have escaped *x*-ray effects, while in a few cases under similar conditions injuries have occurred, can be accounted for only by the existence in a few individuals of certain factors rendering them more susceptible to *x*-ray influence. Such a statement as Kienböck's, founded as it is absolutely upon personal opinion regardless of recorded facts, needs to be challenged. It is most mischievous in the influence which it may have upon technique; and there are enough *x*-ray injuries due to faulty technique without throwing out so well-established a fact as personal idiosyncrasy to account for some of them.

Question of Dangerous and Safe Exposures.—Codman * has considered more extensively than any one else the question of the intensity of *x*-ray exposures which have caused injury in the various recorded cases. His table covers this subject more recently and more extensively than any other has done, and it is worthy of reproduction (see page 242) as bearing upon this extremely important topic.

In this table it is seen that the exposure required to produce injury in cases recorded varies from 0.08 of a minute at one inch distance, to 240 minutes at one inch distance. Assuming that the light in both cases was the same, here is a variation of 3000 units between the susceptibility of the two patients. Of course it cannot be rightly assumed that the light in both cases was the same, but it can be easily assumed that the light in the one case was not 3000 times or even 300 times as great as it was in the other. In contradistinction to this case, where an exposure equivalent to 0.08 of a minute at one inch distance caused a severe dermatitis, E. E. King † records a case of exposure of the hands for three to four months for from two to six hours daily before *x*-ray effects developed. I have in my records one case (Case 37) in which 243 exposures, equivalent to one-half minute at one inch distance from the target, were given in the course of sixteen months, without at any time causing more than slight dermatitis.

In the therapeutic use of *x*-rays when one has occasion to

* Phila. Med. Jour., 1902, ix, p. 438.

† Canadian Practitioner, 1896, xxi, p. 789.

No. of Case.	Inches from Tube.	Exposure in Minutes.	Days of Incubation.	Severity.	Comparative Time at 1 Inch—Minutes.
102	19.68	30	1	severe	0.08
72	15.00	30	14	mild	0.13
66	11.81	25		severe	0.18
113	10.00	20	7	medium	0.20
97	10.00	21	21	severe	0.21
112	8.00	15	3 hrs.	medium	0.23
124	6.00	20	2 hrs.	medium	0.55
16	10.00	60	6	severe	0.60
87	3–4	10	14	severe	1.11 or 0.63
38	8.00	45		severe	0.70
96	3.94	17	8	medium	1.11
75	7.88	78		severe	1.27
19	(patient 6 in.)	(oper. 15.32)			1.43 or 8.88
49	5.46	45	14	severe	1.50
45	5.85	52		medium	1.51
57	6.24	60	during	medium	1.54
62	6.00	60	14	severe	1.66
33	5.00	45	7	severe	1.80
156	6.00	75	2	severe	2.08
39	5.00	60	1	severe	2.40
52	4.29	45	2	severe	2.44
85	11.00	300		severe	2.48
63	8.00	180	10	medium	2.81
53	3.94	50	5	mild	3.28
41	3.00	30	28	medium	3.33
127	2.00 or 1.00	15	10	medium	3.75 or 15.00
139	4.00	60	10	severe	3.75
132	2–8 in.	300	at once	severe	75.00 or 4.69
148	1.5 cm.	25	1	severe	162.50 or 5.32
125	6.00	270	21	severe	7.50
126	6.00	270	21	severe	7.50
54	3.94	120	3	mild	7.89
1	15 cm. for 9 cm. for	40 90	2	severe	8.51
143	3.00	1.50, 1.20	2	severe	16.66 or 11.11
71	3.94	2.10		severe	13.80
149	1.25	30	9	severe	19.20
59	1.96	80		severe	21.05
105	3.00	200	during	medium	22.22
15	1 (?)	30	5	severe	30.00
153	0.625	12	11	medium	30.23
47	2.00	150	2	severe	37.50
55	3.94	1200		mild	78.90
141	0.39	20	6	severe	129.00
40	0.50	60	21	mild	240.00

"Note.—The writer is fully aware that these figures are far from accurate, owing to the lack of proper data in distance from the platinum or glass wall. For instance, in the last two numbers, if we allow an inch for the radius of the tube, we find that the time in minutes at one inch would read 10.53 and 26.60, instead of 129 and 240. In the cases in which the distance is considerable the change would not be so great. The figures are poor at best, and serve more to suggest a method of comparison for the future, than an as absolute figures for the past. . . . . The minimum recorded exposure which has produced injury is then (Case 102) equivalent to only 0.08 of a minute or 5 seconds at one inch. . . . . This figure may be assumed to represent the extreme grade of idiosyncrasy on the part of any patient hitherto examined—one case in a million."

give exposures daily or very frequently over a long period of time the opportunity to observe personal idiosyncrasy is excellent. It has been my constant experience to see variations in the susceptibility of the tissues of different individuals to the influence of *x*-rays. One patient will develop *x*-ray irritation after repeated exposures during two weeks. Another patient, under conditions of technique which are as nearly identical as care can make them, will not develop a similar irritation until two months have passed. He may then develop a reaction which is no greater, which runs no longer course, and which differs in no essential particular in degree or character from the reaction of the other individual, which was set up at the end of two weeks of similar exposure. This variation in the susceptibility of individuals to the influence of *x*-rays is a fact beyond question. Any extended observation upon cases under treatment by exposure to *x*-rays must establish it. And this fact must be taken into consideration in the application of the agent. It is the one fact whose avoidance requires the most care in the application of *x*-rays to therapeutic purposes.

The variation, however, in the susceptibility of individuals to *x*-ray effects has never been sufficient in my experience to amount to marked idiosyncrasy. The variation which I have mentioned above, which may perhaps be said with sufficient accuracy to amount to a difference of four times the susceptibility in one case over that in another, is about as extreme variation as I have seen in my experience with very few exceptions, such as the case mentioned above, in which 243 exposures were given in sixteen months.

It may be said, therefore, I believe, that a moderate variation in the susceptibility of individuals is constantly found, but that this difference rarely amounts to more than four times as great susceptibility in one individual as in another. In extremely rare instances this susceptibility amounts to a marked idiosyncrasy, but this idiosyncrasy is excessively rare. On the basis of Codman's statistics, for example, it occurs less frequently than once in ten thousand individuals.

There have been some suggestions that different parts of

the body in the same individual vary in their susceptibility. Kienböck * states that "the different regions of the surface of the body react in a varying manner. The mucous membranes react most rapidly, and in order of lessening rapidity the skin of the face, of the backs of the hands, the nail matrices, the skin of the extremities, and of the trunk. Over the hairy surface of the head the hair comes out very easily without the appearance of any sign of erythema; there the skin is tightly bound down to the underlying tissue—and the more tense it is, the less is the tendency to superficial inflammatory appearances." Scholtz † also suggests similar variations of different parts of the body. Most other observers have not found such variability. Certainly I have not found it myself. The parts that are tanned by exposure to sunlight react perhaps a little less readily than covered parts, but even this is not established. Indeed my experience does not give any ground for the supposition that different parts of the skin differ in any material extent in their reaction to the influence of *x*-rays. I have not even found that individuals with delicate fair skins are liable to show greater susceptibility to *x*-rays than individuals with darker or more tolerant skin. Variations in these particulars seem to be purely a matter of personal equation of the tissues without discoverable characteristics upon which increased susceptibility or decreased susceptibility may be predicated.

The only part which I have found to show particular susceptibility to *x*-rays is the eyes, and this of course is due to their peculiar structure. Cases of conjunctivitis from *x*-rays have been reported by King ‡ and Scherer.§ Scherer's patient also had an incipient retinitis, which he thought was due to *x*-rays. Conjunctivitis is readily produced by *x*-rays, and the process, by involving the cornea, may become dangerous to sight. Following the suggestion of Oudin, Barthélemy, and Darier, that the most highly differentiated epithelial

* Wien. klin. Wochenschr., 1900, xiii, p. 1153.
† Arch. f. Derm. u. Syph., 1902, lix, p. 241.
‡ Canadian Practitioner, 1896, xxi, p. 789.
§ New York Med. Jour., 1901, lxxiv, p. 543.

elements were most susceptible to *x*-rays, I * called attention to the possibility of atrophy of the rods and cones of the retina from *x*-ray exposures. Apparently that danger was more theoretical than practical, for the effect upon the conjunctiva and cornea will in all probability become severe before the effect will show on the retina. Scholtz † upon this particular point believes that the only effect produced on the eyes by *x*-rays is conjunctivitis, and that there is no effect on the retina.

Influence of Other Factors on Susceptibility.—Various factors in the patient have been called upon to explain variations in susceptibility, as, for example, variations "in the dryness or dampness of his skin; in his electrical resistance; in his anemia or plethora; in the acidity or alkalinity of his sweat; in his vasomotor irritability." ‡ In my experience I have not been able to determine the influence of any such factors. I have repeatedly exposed cases showing the widest variations in the conditions of the skin; surfaces that were unbroken and surfaces that were ulcerated; skins that were clean and skins that were dirty or covered with medicine; skins that were dry and skins that were covered with sweat; patients that were markedly cachectic and patients that were healthy;—and I have never seen any reason to believe that any of these factors was of appreciable importance in determining the production of *x*-ray effects on the skin.

Immunity.—Lancashire § has offered the opinion that the production of dermatitis is a matter of idiosyncrasy, and that immunity against it may develop. I have seen nothing in my experience to give color to the opinion that immunity is likely to develop. I have never seen any reason to believe that patients become more tolerant of *x*-rays after being for a long time under their influence than they were at the start. On the contrary, it has seemed to me that an increased susceptibility developed, and certainly it is easier to produce dermatitis after a previous dermatitis has occurred, unless a sufficient

* Jour. Amer. Med. Assoc., 1902, xxxviii, p. 911.
† Arch. f. Derm. u. Syph., 1902, lix, p. 99.
‡ Codman, loc. cit.
§ Brit. Med. Jour., 1902, i, 1328.

time has elapsed for the tissues entirely to regain their normal condition.

Anodyne Effect of X-rays.—Many observers have called attention to the marked anodyne effect of *x*-rays in painful conditions. The relief of pain in carcinoma has been noted by various observers; among others: Sequeira,* Pfahler,† Johnson and Merrill,‡ Ayers,§ Ferguson,‖ Clark,** Soiland,†† Eijkman,‡‡ Morton,§§ Despeignes,‖‖ and Gocht.*** The cases in which this effect has been observed vary from epitheliomata to extensive and deep-seated carcinomata. Despeignes, so early as 1896, reported the relief of pain in carcinoma of the stomach. Similar marked effect in relieving the pain of sarcoma has been reported by Kirby,††† Ricketts,‡‡‡ Burdick,§§§ Coley,‖‖‖ and others.

The anodyne effects of *x*-rays are not confined to malignant diseases. Sokolow**** has reported the marked relief of pain in rheumatism. Escherich de Graz †††† reports the relief of pains of rheumatoid arthritis. Gocht ‡‡‡‡ has reported a very severe case of trigeminal neuralgia, for which the patient had used morphin, which was entirely relieved by fourteen *x*-ray exposures. Stembo §§§§ has reported twenty-eight cases of various forms of neuralgic conditions, of which twenty-one, or 75 per cent., were promptly relieved. Relief usually followed

* Brit. Med. Jour., 1901, ii, 851. † Phila. Med. Jour., 1901, viii, 1085.
‡ Phila. Med. Jour., 1900, vi, p. 1089.
§ K. C., Medical Index-Lancet, 1902, xxiii, p. 18.
‖ Brit. Med. Jour., 1902, i, p. 265. ** Brit. Med. Jour., 1901, i, p. 1398.
†† South. Cal. Practitioner, 1902, xvii, p. 140.
‡‡ Krebs und Röntgenstrahlen, Haarlem, 1902.
§§ Med. Record, 1902, lxi, p. 361. ‖‖ Semaine Médicale, 1896, xvi, 146.
*** Fortschr. a. d. Geb. d. Röntgenstrahlen, 1897, i, 14.
††† Journal of Advanced Therapeutics, 1902, xx, p. 89.
‡‡‡ Jour. Am. Med. Assoc., 1900, xxxiv, p. 76.
§§§ American Electro-Therapeutic and X-Ray Era, 1901, i, No. 7, p. 1.
‖‖‖ American Medicine, 1902, iv, p. 251.
**** Russky Vratch, 1897, No. 46. Abst. Fortsch. a. d. Geb. d. Röntgenstrahlen, 1898, i, p. 209.
†††† Revue des maladies de l'enfance, 1898, xvi, p. 242.
‡‡‡‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1897, i, p. 14.
§§§§ Therapie der Gegenwart, 1900, ii, p. 250.

three exposures. Leigh * has reported a case of a young man who had a bullet in his thigh, which was much swollen and extremely painful; the next day, after a long exposure to *x*-rays, made for the purpose of taking a photograph, the pain was relieved, and on the third day the man was able to walk. The relief of itching in eczema and in lichen planus has been reported by Scholtz,† and similar relief in eczema has been reported by Hahn and Albers-Schönberg.‡

Variations from the normal in the sensibility of parts affected by *x*-rays have been noted by several observers. Gilchrist § and Oudin, Barthélemy, and Darier‖ have called attention to the loss of sensibility in *x*-ray burns under their observation. Prince ** reported upon this point in the case of a burn of the back of his hand, as follows: "The sense of touch is affected throughout the entire area of inflamed skin on the dorsal aspect of the fingers of the left hand. It is completely lost on this surface of the second and third phalanges of the index, middle, and ring fingers, and gradually shades into normal cutaneous sensibility over the proximal phalanx of each of these fingers. The little finger of this hand shows hypesthesia near the tip only. In the anesthetic areas a needle point is felt slightly as a touch, and this hypalgesia shades into normal sensibility to pain *pari passu* with the restoration of touch sense. On the sides of the fingers pain and touch are felt normally. Heat and cold are appreciated with equal readiness in either hand." Hyperesthesia has been noted by Barthélemy †† in a case in which there was no anesthesia but points of hyperesthesia.

The testimony as to the relief of pain by the use of *x*-rays is almost universal among workers in this field. I have had repeated opportunities to observe it in my experience. It constantly happens that patients suffering from painful diseases voluntarily state, after a few exposures, that the pain is greatly

* American X-ray Journal, 1899, iv, p. 559.
† Arch. f. Derm. u. Syph., 1902, lix, p. 421.
‡ München med. Wochenschr., 1900, xlvii, pp. 284, 324, 363.
§ Johns Hopkins Hosp. Bull., 1897, viii, p. 17.
‖ Monatshefte f. prakt. Derm., 1897, xxv, p. 417.
** Phila. Med. Jour., 1902, x, p. 199.
†† Annales de Dermatologie, 1901, xxxii, 4e Série, vol. ii, p. 174.

or entirely relieved. This relief is not confined to superficial conditions, but has been seen in deep-seated painful conditions as well. This occurrence is too frequent and too positive to be a coincidence or the result of suggestion. It is rare for painful malignant diseases not to be somewhat relieved by *x*-ray exposures, and frequently after two or three exposures the relief will be complete, and may persist as long as the exposures are continued, and perhaps for weeks after they are stopped. Were this relief of pain seen only in malignant diseases, it might be possible that the effect was only produced indirectly by interference with the growth of the tumor. The promptness, however, with which this relief occurs is against this supposition, and the further fact of the frequent prompt relief of pain in neuralgias leaves little room for doubt that the relief of pain is to be attributed directly to an intrinsic anodyne quality of the rays.

Burdick * has reported a case of osteosarcoma in which extreme pain followed a short time after *x*-ray exposures, but the description of the case does not make it clear that this might not have been due simply to remaining in a cramped position for several minutes, or some such accidental fact. I have never seen such an occurrence. In one case of very extensive disease of the scalp and face, which was either tuberculosis of the skin or blastomycosis, the patient complained of slight pain after *x*-ray exposures. Both eyes were gone and she was in a highly nervous state, and we were not able to determine positively that the increase of pain was not due to suggestion, though it seemed likely that the pain might be justly attributable to the *x*-ray exposures. Aside from this, I have never seen an increase of pain after *x*-ray exposures in which there was any reason to believe that the increase was attributable to the *x*-rays.

* American Electro-Therapeutic and X-Ray Era, 1901, i, No. 7, p. 1.

CHAPTER II.

THE HISTOLOGICAL CHANGES PRODUCED IN TISSUES BY X-RAYS.

STUDIES of the histological changes in the tissues produced by *x*-rays have been made by Kibbe, Gilchrist, Oudin, Barthélemy and Darier, Behrend, Unna, Grouven, Gassmann, Salamon, Scholtz, and others. One of the first studies is that made by Kibbe,* of Seattle. He excised, without local anesthesia, a piece of skin one centimeter square from an area of deeply discolored dry dermatitis. "The histological changes were as follows: The stratum corneum was apparently unchanged; stratum lucidum not clearly visible, excepting over small areas, where the underlying disturbance was seen to be slight. The outer layers of the cells composing the rete mucosum presented the most striking alterations, particularly the nuclei. Taking the stain both with hematoxylin and lithium carmin very feebly, the nuclei showed in addition a peculiar granular change, which was first indicated in those retaining a more normal reaction to the stain by the formation of a fine nucleolus, which could be seen here and there in the process of division. Near the stratum granulosum the bodies of the cells were apparently becoming converted into keratohyalin as a first step to the increase in bulk, as it were, of the stratum granulosum by a development in their interior of coarse granules, staining deeply with hematoxylin, and also with carmin. With the former they appeared like blotches of India ink; in some places giving the impression as though the cells had been charred by heat. This was particularly the case around the hair follicles. The corium exhibited the ordinary changes found in mild dermatitis: capillary dilatation, with collections of round cells scattered through its structure, particularly around the hair follicles. No extravasations of blood were noticed."

* N. Y. Med. Jour., 1897, lxv, p. 71.

Gilchrist * has examined skin from dry, red, exfoliating dermatitis. "Two portions of skin were excised for histological purposes on the first day. One portion was taken from the dorsal surface of the phalangeal region of the third finger, and the other from the lateral margin of the hand over the base of the metacarpal of the little finger. Neither stained nor unstained sections demonstrated the presence of any foreign particles, and only showed chronic inflammatory changes. The horny layer was thickened and half of it was partially detached. A large number of brown pigment granules were found in the exfoliating portion. The mucous layer was not thickened, but it was more pigmented than normal. In the corium the vessels were dilated and the pigment cells of the papillæ were almost as numerous as are usually found in a section of negro skin. It was suggested that particles of platinum might have passed from the tube through the glass bulb deep into the tissues. Portions of exfoliating skin were accordingly submitted to Professor Abel for chemical analysis, and he has very kindly furnished me with the following brief report: 'I could find no platinum in the pieces of epidermis that you left with me for analysis.' "

Alopecia in Guinea-pigs.—Oudin, Barthélemy, and Darier † have made a careful study of skin taken from areas of alopecia produced experimentally in guinea-pigs by *x*-ray exposures. Their findings are as follows:

"The bulbar end of the hairs is atrophic and thin and contains no pigment. The bulb is full but very soft." ‡

"Skin from areas of alopecia showed, first, an enormous thickening of the epidermis in all its layers; second, the atrophy of the hair follicles, which in places had entirely disappeared."

Epidermis.—"The horny layer is markedly thickened, but the individual cells have preserved their normal structures.

* Johns Hopkins Hosp. Bull., 1897, viii, p. 17.

† Monatshefte f. prakt. Derm., 1897, xxv, p. 417.

‡ Wood (Lancet, London, 1900, i, p. 231) has examined the hairs which had fallen out in alopecia produced in man by *x*-rays. His description is as follows: "The shed hairs were brittle and pale in color, with atrophic bulbs, while microscopically the normal striation was indistinct and the medullary substance appeared to be collected into separate nodes with clear intervening spaces."

The prickle-cell layer and the palisade layer have also increased in thickness enormously; their height, as shown by the micrometer, is ten to fifteen times as great as normal. The individual cells are larger, but especially they are much more numerous, there being ten or twelve rows of cells in the Malpighian layer, and six to ten rows of cells showing keratohyalin, while in normal areas there are only one, sometimes two, and two to three rows respectively. The prickle cells are only slightly changed in individual appearance, and as the piece of skin cut out was white, they show very little pigment, and those in the first rows show numerous karyokinetic figures. The polygonal cells show nothing abnormal either in protoplasm, nucleus, or intercellular fibers. The cells become more flattened the nearer they lie to the horny layer, and contain kernels and balls of eleidin (keratohyalin), which increase in number toward the horny layer, while the cell nuclei become more and more atrophic. The kernels of eleidin become very numerous, and of a truly enormous size. There can be seen often cells with one, three, or four such kernels, as large as the nucleus of a Malpighian cell. They are round or irregular in shape, strongly refracting, and stain a bright red with carmin."

Hair and Sebaceous Follicles.—"Normally the hair follicles stand close to each other in little groups, with small glands lying near them, and thin smooth muscle; there are eight or ten hairs in each field at the medium magnification. In the affected skin, on the contrary, not a hair can be seen, and there remain only traces of the follicles; one, or at most three, in each field. These are no longer follicles, but merely downward projections of epidermis. There is no suggestion of a hair papilla, or of any beginning regeneration. There is nothing more to be seen of the sebaceous glands or of the muscle. Sweat-glands are absent in the normal skin in this region."

Cutis.—"The changes in the cutis are of a nature only slightly in accord with those in the overlying epidermis. It can be noticed merely that the cells are somewhat more numerous, the connective-tissue fibers have a more parallel arrangement, and the elastic fibers around the hair follicles are wrinkled

and atrophic. The papillæ of the cutis are higher and wider in the bare spots and in places contain pigment cells. The connective tissue and elastic reticulum of the corium are normal. The small vessels of the cutis and the larger ones of the subcutis are also normal. No changes in the nerve-fibers could be recognized in the sections.

"The destruction of the hair follicles and epidermis, while the cutis and vessels are only in the slightest degree altered, is very significant. The thickening of the epidermis in all its layers, the enormous increase in the keratohyalin, and the extreme atrophy of the follicles, are to be looked on as a reaction against an irritation of unusual severity. This irritation seems to increase the vitality of the least differentiated tissues; while it produces degeneration and atrophy of the more highly differentiated structures—hairs, nails, and glands. Whether this atrophy is the result of nervous influence, of obliteration of the vessels, or of circulatory disturbance, we do not as yet know."

Unna* has investigated the brownish pigmented skin of a woman who, several weeks before death, had been repeatedly exposed to *x*-rays. He found increase of pigment in the papillæ, around the vessels, and in the outer layers of the cutis, but not in the epidermis. Numerous mast cells were present around the vessels. The collagenous fibers of the cutis were swollen, and so pressed on each other that the lymph-spaces were only indicated. The elastic fibers did not stain, as normally, with acid orcein, but were otherwise unchanged. A large number of the fibers of the cutis did not take the normal stain with the safranin-water blue method, but took a basic red stain, showing that they had become basophile. These fibers were penetrated by transverse, longitudinal, and spiral crevices, and thus separated into irregular fragments.

An extensive study has been made by Scholtz† upon the histology of tissues affected by *x*-rays. It is worthy of being quoted *in extenso*. In his experiments pigs were chosen for the exposure because their skin most closely resembles human skin.

* Deutsch. med. Ztng., 1898, xviii, p. 197.

† Arch. f. Derm. u. Syph., 1902, lix, p. 241.

Experiment 1.—"A small strip of skin on the back of a young pig was exposed to the *x*-rays for one hour at 24 cm. distance, and after twenty-four hours excised. No macroscopic changes. No definite microscopic changes, except that possibly the protoplasm of the prickle cells is slightly more diffusely and deeply stained than normal, and the cell outline is not quite so distinct. The protoplasmic fibrillæ stain distinctly."

Experiment 2.—"Similar exposure, excision after seven days. Macroscopically the hair is loosened; no other definite changes. Microscopically: the horny layer is somewhat loosened and shows a few nucleated cells. The stratum granulosum is only intimated, and in some places has entirely disappeared. The prickle-cell layer is evidently diminished, and the cells themselves are much altered. They are everywhere swollen, their outlines have disappeared by degrees, and in the palisade layer they are pressed out into a wider shape. The protoplasm is given a relatively more diffuse color with hematoxylin, while the nucleus is only slightly stained and its chromatin is divided into little crumbs. The nuclei are greatly swollen and often angular and vacuolated; the protoplasm, and especially the nuclei, both show vacuoles.

"In almost every field are cells with nuclei divided into two or three without mitosis. Mitoses are not present at all, or only show a beginning. These evidences of degeneration are apparent everywhere from the palisade layer to the horny layer. Near the external surface the outlines of the cells are hardly visible, and their protoplasm has blended into a homogeneous mass. The nuclei are for the most part shadows. In the hair follicles and sheaths the changes in the cells are entirely analogous; and the loosening and falling of the hairs is easy to understand in the light of this cell degeneration.

"The corium is œdematous; the connective-tissue fibers do not stain well, are somewhat swollen, and homogeneous. The 'basophile reaction' which Unna mentions is not, however, found. The elastic reticulum is still present. No change is apparent in the small vessels. Evidences of inflammation are only intimated. The connective-tissue cells show changes in a slight degree. They have a clear protoplasm, more or less

diffusely stained, are swollen and often of peculiar shape. The cells of the sweat-glands also show a similar slight degenerative change, with occasional proliferation, and have here and there dropped out into the gland lumen. In the larger vessels there is present in the media, and especially in the intima, slight cell degeneration, altogether analogous to that seen elsewhere. The cells of the intima are swollen, project into the lumina of the vessels, in some places show evident proliferation, with a tendency to fall off into the blood-current."

Experiment 3.—"Back of a young pig exposed daily for nine days, fifteen minutes each, at a distance of 15 cm. Excision twenty-four hours after last exposure. Macroscopically: hair beginning to fall out, slight appearance of atrophy and redness of skin. Histologically: changes throughout analogous to those in Experiment 2, but more decided; in addition, beginning inflammatory reaction. In the corium, especially around the vessels, there is a slight infiltration with round cells and single polymorphonuclear cells; and a few of these are also already present in the rete. The smaller vessels, especially of the papillæ, seem to be somewhat dilated."

Experiment 4.—"The ear of a pig was exposed eleven times for fifteen minutes each at a distance of 15 cm. Six days after last exposure a triangular piece was cut out of the edge of the ear. Macroscopically: hair fallen out on both surfaces, skin reddened, with an atrophic appearance; on the outside, especially near the middle of the ear, slight raising of the epithelium in blisters. Microscopically: degenerative changes of the cellular elements similar to, but more marked than, those of Experiments 2 and 3. Diminution in thickness and homogeneity of the epithelium more marked, active inflammatory reaction, with thick infiltration with polymorphonuclear leucocytes. Masses of leucocytes are passing toward the epithelium; some have pushed between and in the degenerated epithelial cells, so that one gets the impression that here the leucocytes are playing a truly phagocytic rôle. Below the infiltrating cells are numerous heavily loaded mast cells. Toward the center of the exposed area the horny layer, alone or with the few remains of the rete, is raised in bl masses

of leucocytes under it; and in the more strongly affected places the horny layer is completely lacking, and here are the first beginnings of the so-called *x*-ray ulcer. The elastic reticulum is more poorly stained, but is still intact. The changes in the connective tissue resemble those in Experiment 2. The cartilage of the ear is unaltered. In the large vessels the cells of the intima and media are greatly changed; they appear swollen, the protoplasm diffusely stained, the nuclei pale, and the chromatin in crumbs. Two, three, and four nuclei are often to be seen in one cell as the result of amitotic splitting of the nucleus without cell division. Protoplasm and nuclei show general vacuolization, and here and there large vacuoles are apparent. The swollen cells of the intima float detached in the lumina of the smaller vessels. The lumina are otherwise still intact, and filled partly with blood-corpuscles, partly with an uncolored thready mass of particles, in which bands of fibrin are only exceptionally visible. The cells of the sweat-glands are also markedly degenerated and vacuolated, the lumina being partly filled with leucocytes.

"Where the rete projects down into the cutis as the outer sheath of the hair follicles, similar degenerative processes are to be seen in the cells, and the same inflammatory reaction is present as above. The hair follicles are almost completely destroyed, and in their places are collections of leucocytes."

Experiment 5.—"Skin of back of pig exposed 9 times, fifteen minutes each, at 15 cm. Excised eight days after last exposure. Macroscopically: Röntgen ulcer. Exposed portion of skin, which began to get moist four days after last exposure, is now superficially necrotic and covered with a thin fibrino-purulent exudate. The area has the appearance of a purulent burn of the second degree. Microscopically: the changes resemble those in the beginning of *x*-ray ulcer, described in Experiment 4, showing a more severe degree. There exists now no trace of the rete Malpighii or of the horny layer; in place of them is a thick layer of well-formed leucocytes, polynuclear predominating. These pus cells lie close to each other, interpenetrated by a fine fibrillar material which is the only fibrin revealed by Weigert's stain. Above this layer of leuco-

cytes there exists a thin layer composed of pus cells, detritus, remnants of nuclei, and, most numerous, bacilli and cocci, which therefore stains by Gram almost uniformly a dark violet. The *x*-ray ulcer is thus composed of masses of leucocytes, remains of cell protoplasm and nuclei, and bacteria. This is sharply defined toward the corium in some places, while in others it shades off into a zone of connective tissue infiltrated with pus cells.

"The papillæ are for the most part still normal in outline, or at least recognizable. The connective-tissue fibers, just under the ulcer especially, are soaked in serum and in places are split up into very fine fibrillæ. The elastic reticulum is still present in its entirety. The connective-tissue cells show, as in Experiment 2, degenerative processes to a pronounced extent. Their protoplasm is usually swollen and stains diffusely with hematoxylin, and the single or multiple nuclei are also swollen, the cells presenting various curious shapes.

"The larger vessels show still more marked degeneration, especially of the cells of the intima and media, proliferation and falling-off of the intima cells, and vacuolation of the walls, as described by Gassman and Lion. The smaller vessels are greatly dilated, filled with blood, and surrounded by a wall of leucocytes.

"In the cutis and layer of leucocytes are large and small hemorrhages. Changes in the glands are similar to those in Experiment 4. The hair roots are entirely destroyed, and in their places are collections of leucocytes, among which some remains of nuclei and unstained fibrinous material can be distinguished. Wherever the rete normally has sent processes into the corium are now present extensions of the ulcerative process."

Experiment 6.—"The histological findings in the later stages of more severe *x*-ray ulcers, as I have determined them in three other examinations, can be summed up as follows: The changes in the more superficial layers correspond throughout to those in Experiment 5, but the detritus, remains of cells and nuclei, and bacteria are greater in amount, while the normal leucocytes are less numerous. The degenerative pro-

cesses still affect both the cellular and intercellular elements of the cutis; the cells have taken on an appearance of giant cells, and the fibers of the connective tissue are for the most part dissolved into thin fibrillar material, which still reacts to the fibrous tissue stain. The connective tissue has in general a vacuolated appearance, and is more or less infiltrated with round cells and pus cells. The glands are entirely obliterated, and the larger vessels in places completely destroyed. The dilatation of the smaller vessels, the stasis of blood in them, and the hemorrhages are increased, and their walls in places have degenerated into homogeneous masses. Deeper in the corium the tissues are altogether normal."

Experiment 7.—"In various stages of reaction after exposures in various degrees of severity of human skin, I was able to demonstrate that the *x*-ray changes are entirely similar to those in the skin of the pig. Slight exposures lead to degenerative processes similar to those described, especially in the hair follicles. In general, a more marked vacuolation, especially in the palisade layer, is apparent in human than in pig skin, though the reason may have been in a difference in the method of exposure. Also, pigment was to be found not only in the deep layers of the rete, but also in the outer part of the corium. This strong over-pigmentation seems to take place especially in treatment of psoriasis; at least we have seen its appearance almost always both in the healing psoriatic areas and in the healthy surrounding skin, while in other disease it is a phenomenon of merely occasional occurrence. The changes of higher degree in human skin so entirely resemble those in the pig skin that they need no further description."

Experiment 8.—"The process of healing of superficial *x*-ray ulceration and excoriation I was able to study in human skin, and of course in lupous tissue. The infiltration in the corium vanishes, the cells and nuclei of the connective tissue become again normal, and where the papillæ have been destroyed there commences a formation of fine, horizontal connective-tissue fibrillæ. The epithelium grows forward from the edges, sending processes into the still soft and œdematous connective tissue, or stretching over the papillæ which remain. In this

case the normal appearance of the skin is renewed, only the destroyed follicles being lacking. Both the connective tissue and the epithelium in the healed areas remain soft and tender, the latter showing grave disturbances for some time. The cells of the rete remain œdematous, the prickle cells swollen, vacuolated, with swollen and poorly stained nuclei. The prickle-cell layer and the horny layer are often much thickened, and the keratohyalin in the cells is distributed in irregular clumps and crumbs. In the horny layer are nucleated cells not completely cornified. I have noticed, however, in cases in which the process has resulted not in ulceration, but merely in a rather severe dermatitis, similar appearances in these layers some weeks after the cessation of exposures. Thus it is easy to understand why fresh *x*-ray scars and strongly exposed areas of the skin are extremely sensitive both to caustics and to *x*-rays themselves, and, for instance, how the application of pyrogallic salve quickly causes renewed ulceration, which then heals very slowly. We had occasion to see three typical instances of this."

"The following conclusions may be drawn from my histological observations:

I. "X-rays influence especially or exclusively the cellular elements of the skin. These are influenced primarily, and undergo a slow degeneration, while the connective tissue, the elastic tissue, musculature, and cartilage are changed only in a slight degree, and suffer only secondarily, as a result of the cellular degeneration and the inflammatory reaction consequent to it."

II. "The degeneration affects the epithelial cells in the highest degree, and to a less extent the cells of the glands, the vessels, the muscular tissue, and the connective tissue."

III. "The degenerative appearances are of various kinds, and affect both the protoplasm and nuclei."

IV. "As soon as the degeneration of the cells has reached a certain point, an inflammatory reaction appears, which manifests itself in a marked dilatation of the vessels, with gathering leucocytes and marked emigration of the blood-

corpuscles. When greater cell degeneration occurs as a result of stronger exposure, collections of leucocytes press into a mass of degenerated cells and accomplish their further destruction."

V. "The changes in the large and small vessels are apparently of great importance as affects the further development and slow healing of the ulcerations."

Gassmann * has examined tissues from the border of *x*-ray ulcers. The changes that he finds in the tissues are practically the same as those already described. He gives an accurate description of the changes in the blood-vessels as follows:

"Important changes are noticeable in the vessels. The walls of the small vessels and capillaries in the upper zone of the ulcer are changed into irregular swollen masses, the lumen being sometimes entirely obliterated and sometimes filled with corpuscles, in which latter case the vessel is surrounded by a collection of infiltrating cells. The intima is thickened and the endothelial cells are swollen, and often detached from the wall. The small vessels of the deeper tissues show similar changes of the intima, the lumen often being entirely or partly obliterated. In the larger arteries and veins of the subcutis the intima is thickened, there is proliferation of the endothelial cells, filling perhaps half of the lumen. The intima shows numerous vacuoles and crevices. The muscular layer also shows vacuoles; the cells seem to be pressed together, are smaller, and the fibers between them do not stain well. Leucocytes are present in the media, and more numerously in the adventitia. Neither the inner nor outer elastic layers are compact, but both are loose, the fibers separated from each other by spaces and increased in number. Not all, but many, of the large vessels show these changes. The lumina are sometimes empty though not obliterated, sometimes filled with blood."

Microscopic Changes in Psoriasis under X-rays.—Scholtz † gives the following description of a study of psoriasis:

"An area of psoriasis was exposed from May 31 to June 6 five times, ten minutes each, at 40 cm. distance. June 8 the

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1899, ii, p. 199.

† Arch. f. Derm. u. Syph., 1902, lix, p. 241.

scales were completely fallen off and the psoriatic area was already completely smooth and colored with dark brown pigment. The healthy skin in the vicinity was also slightly colored. At this time a piece was excised containing both healthy and psoriatic tissue.

"Microscopically the typical alterations of psoriasis were almost entirely vanished. Only the prickle-cell layer and stratum granulosum in the diseased area were still somewhat thickened, and there was some infiltration of the papillæ and around the subpapillary vessels of the corium. The epithelial cells themselves again showed the usual changes. The healthy as well as the diseased tissues were peculiarly pigmented. In one place in the corium, especially in the papillæ and near the palisade layer, were cells, some long, some star-shaped, with irregular nuclei, whose protoplasm was stuffed full of round, large, yellowish-brown particles of pigment. Also there were in the rete Malpighii several similar cells (leucocytes) between the epithelial cells. Moreover, the cells of the rete, especially in the deeper layers, contained in their protoplasm fine particles of the same color, and a fine network of particles of pigment lying close to each other, seemed to be interwoven around these cells. Closer examination leads me to believe that we have here to do not with intercellular pigment, but with particles deposited in the edges of the epithelial cells themselves, in their protoplasmic fibrils. In favor of this view are the club-shaped projections toward the corium, and the observation that the protoplasmic fibrils in the areas rich in pigment do not stain well, as has been described by Kromayer. It will, however, require further research to determine this point. This pigment gave no reaction for iron with sodium ferrocyanide and HCl."

Microscopic Changes in Lupous Tissue.—Scholtz's * study is as follows:

I. "Rather deep lupous area on breast, which is deeply infiltrated, thickly set with tubercles, and covered with a thin crust. *X*-ray treatment February 8 to March 7 at intervals, in all ten exposures, eight to ten minutes, at 35 cm. distance.

* Arch. f. Derm. u. Syph., 1902, lix, p. 241.

After a few weeks a severe dermatitis of the exposed surface appeared, with subsequent superficial necrosis of the area. Excision March 17. The area has been for about eight days decidedly reddened and somewhat swollen, with the epithelium raised in blisters in the middle. A piece cut from the edge was hardened in alcohol and Fleming solution. Microscopic examination shows the epithelium in a degenerated homogeneous condition, mostly raised in blisters. The cutis, especially in the lupous area, is thickly infiltrated with round cells and pus cells. The form and typical structure of the tubercles have disappeared, and the tubercles are to a certain extent absorbed. In their place are collections of numerous abnormally large giant cells, single and multiple nucleated cells with swollen, washed-out protoplasm (altered epithelioid cells), and among them mononuclear and especially polymorphonuclear leucocytes in great numbers. The giant cells contain an unusually large number of nuclei, and measure 100 to 200 microns in diameter. Most of them no longer show regular outlines; there is presented a pale irregular mass of protoplasm containing a great number of nuclei, and mingling diffusely with the surrounding tissue. The altered epithelioid cells, which are often polynuclear, show the same appearances."

II. "Excision on March 25. The area is superficially necrotic, and covered with a thin fibrino-purulent exudate. Microscopic examination: Superficial crust similar to that described on the normal skin. The changes in the lupous tubercles are similar to those given above, but still more pronounced. The destruction and absorption of the tubercles, their penetration by round cells and pus cells, and the degeneration of the epithelioid and giant cells have made further progress. Here also the leucocytes seem to be taking an active part in the complete destruction of the degenerated cells."

III. "A similar area after subsequent covering with skin. A piece of the border which showed some suspected lumps, while the rest of the area was free, was chosen for excision. Microscopic examination showed the epithelium stretched out smooth over the corium, with no projections into it, in three or four layers of cells. Its cells still show changes. The

corium is almost free from accumulations of cells. The connective tissue is composed of fine, thin, but well-stained fibers, which for the most part run parallel to the epithelium, and only to a slight extent transversely. In certain places are still apparent some remains of tubercles, principally in the form of bunches of protoplasm with numerous nuclei. Some of these are still penetrated and surrounded by leucocytes, others are circumscribed and encapsulated by fibrils of new connective tissue, some of which cross through them."

IV. "Lupus of the cheek and nose; cheek infiltrated, showing numerous lupous tubercles. X-ray treatment from February 27 to March 7, with one interruption, in all seven exposures, of five to ten minutes, at a distance of 10 cm. to 35 cm. By the middle of March the area is very red and somewhat swollen, but with no ulceration on the cheek. April 1, the inflammatory appearances are entirely vanished. The tubercles are not so numerous and not so apparent as before, but there can always be recognized on pressure with a glass quite a number of small typical or suspicious tubercles. Excision of one such from the middle of the area. Microscopic examination shows appearance of degeneration already marked in the epithelial cells, but regeneration has already begun, the Malpighian layer being especially thickened. In the tubercles are seen changes similar to those in (I), but not so marked. The tubercles are still typical in shape and structure; the changes in the giant cells and epithelioid cells less evident, but still clear. Around the tubercles exists already a definite wall of mononuclear and polynuclear leucocytes, and they are also already penetrated by leucocytes, but the infiltration is not so far advanced as in (I).

"Thus the action of the rays on lupous tissue is entirely similar to that on the normal skin: First, degenerative processes in the cellular elements and epithelioid cells of the lupous tubercles themselves; which are followed by the appearance of an inflammatory reaction.

"The healing of the lupus and the destruction of the bacilli result thus from the reactive hyperemia and inflammation, and we can draw no deduction as to any bactericidal properties of the *x*-rays. The principal peculiar important effect of *x*-rays

in the treatment of lupus lies in the reactive inflammation concentrated upon the affected spot, which results from the degenerative processes induced in the tubercles. The reaction to the *x*-rays is similar to that induced by tuberculin, except that it extends over a long period of time."

Grouven * has studied sections from lupus of the cheek, treated ten weeks by *x*-rays. They show a large formation of connective-tissue fibers surrounding and encapsulating the tubercles and running through them, with numerous spindle cells and evidences of new formation. The epithelioid cells and lymphocytes of the lupous tubercles show vacuolization and loss of staining reaction, and degeneration of both nucleus and protoplasm. He describes the course of healing of lupus as follows: Hyperemia, leading to increased diapedesis of leucocytes, first at periphery of nodules, pressing on into interior, changing into spindle cells and new connective-tissue elements. The cells of the nodules undergo degeneration and absorption. and are replaced by connective tissue.

Lepra.—Scholtz † examined tissue from the middle of a nodule of lepra which had been exposed to *x*-rays until redness had appeared. "Some time after the disappearance of this reaction the part of the nodule which had been treated seemed to be a little sunken, but no further change appeared. Five weeks later the nodule was excised.

"Microscopically, the leprous infiltration in the exposed region was slightly reduced. The numerous bacilli seemed to show more granulation than in the unexposed region, but were well stained and undiminished in number, the action of the rays having on them no apparent influence."

The changes here, therefore, are without significance. This fact probably means nothing, because the exposures were not carried far enough to produce effect. Theoretically, there seems no reason why an individual nodule of lepra should not be affected in the same way as a nodule of tuberculosis.

Changes in Carcinomatous Tissue under X-rays.—Scholtz ‡ reports upon his study of carcinoma as follows: "In one case

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1902, v, p. 186.

† Arch. f. Derm. u. Syph., 1902, lix, p. 241. ‡ Loc. cit.

of carcinoma I was able to obtain excisions in the stage of beginning reaction, and also after the formation of a superficial necrosis.

"On the whole, the microscopic examination of the pieces of carcinomatous tissue showed that under the influence of the *x*-rays the cancer cells degenerate and are destroyed, just as the normal epithelial cells. However, the degenerative processes are recognizable, especially in the deeper carcinoma points, only after a relatively more intense action of the rays; and the appearances were often difficult to distinguish from the normal retrogressive processes. In one case, excision after eight exposures of ten minutes each, at 20 cm., fixation in Fleming, and staining with safranin, numerous beginning mitoses were apparent in every field, but nowhere could be seen the normal course of mitotic division. The cells mentioned were filled with intensely stained fibrils and bunches of chromatin, irregularly distributed and of varying thickness, but no division occurred; the chromatin seemed to reunite into single rings and bunches."

I have examined tissue taken from carcinomata in various stages of subsidence under the influence of *x*-rays. The findings in all have been practically identical. The following case presents accurately the histological conditions found in all the cases examined: On December 5, 1901, a piece of tissue was excised from the border of a carcinoma ulcer on the cheek (see Case 53, Fig. 127). This case had had ten *x*-ray exposures, and at the time was just beginning to show the first trace of irritation. Its nodular character had not been altered. The first indications of effect on the growth were just appearing. The tissue was put through 4 per cent. formalin and alcohol, imbedded in celloidin in the usual way, and stained with hematoxylin and eosin. The notes * of the examination are as follows: The tumor is composed of epithelial cells, arranged in more or less circular, oval, and narrow groups, in glandular

* The notes of this case are condensed from notes made by Mr. E. H. Ruediger, to whom I am indebted for valuable aid in this work. It is due Mr. Ruediger to say that this description was written without any knowledge of the observations, which are so strikingly similar, made by other observers.

and tubular form, and these islands of tumor cells are surrounded by fibrous tissue stroma (Fig. 93). Diagnosis, glandular carcinoma of the skin. Blood-vessels are found in various parts of the stroma, but none are seen in the islands of tumor cells. At the periphery of the islands, where evidently the growth of the tumor has been most pronounced, and the youngest tumor cells exist, there is a peculiar breaking-down and disappearance of the cells. The outline of cells here is vague or lacking. The nuclei are fragmented and the fragments scattered, or at least spread apart, leaving merely dim, shapeless remnants that take a pale blue stain. In some of the blood-vessels, especially those intimately connected with the tumor tissue, which make themselves quite prominent by areas of broken-down tumor cells surrounding them, there is an extreme degree of endarteritis, almost or entirely obliterating the lumina. Other blood-vessels lying more distant from the islands of tumor cells show no such change.

On February 8, 1902, or about two months after the first tissue was taken, a second piece was excised from relatively the same point in the border of this ulcer. At the time the border of the ulcer had flattened down completely, and had entirely lost its nodular character. The notes of examination of this specimen are as follows: Microscopic examination now shows scarcely a trace of tumor left (Figs. 94 and 95). Beneath the epidermis there is a considerable layer of fibrous tissue in which there are areas staining pale blue with hematoxylin similar to the blue material found at the periphery of the islands of tumor cells described in the tissue excised December 5. There are seen occasionally, also, some granules which appear to be fragments of nuclei. The areas which have been occupied by tumor tissue are now being filled by connective tissue. The normal tissue shows nothing unusual. There are sweat-glands and muscle-fibers, having the same appearance as in healthy and untreated tissue, and the surrounding blood-vessels show no such endarteritis as is described in the tissue examined two months ago.

In other words, in this case there was a sufficient reaction to destroy the highly susceptible carcinoma cells, while the

surrounding healthy tissue was much less affected and was already regaining its normal condition.

In one of my cases of carcinoma of the breast in which the breast was obtained after death, histological changes corresponding in all essential respects with the above were found well down in the substance of the breast by Prof. W. A. Evans, of the University of Illinois, so that there is no doubt that these changes can be produced beneath unbroken healthy tissue.

Considering the tissue excised at different times, the salient features found in the histological examination are these:

The first changes occur in the cells at the periphery of each nest of carcinoma. Later the same process involves all of the mass, invading in succession the cells from the periphery to the center. These cells are found in various stages of destruction, or, if such it may be called, necrosis. The term necrosis, however, as ordinarily used, does not accurately describe the process as it occurs under *x*-rays. In the ordinary form of necrosis the cells retain more or less completely their form, and the first change noticed is in the nuclei, which fail to take the basic stain, while the tissue in general takes a diffuse acid and basic stain, apparently a mixture of the two. On the other hand, in the tissue breaking down under *x*-rays the cells and nuclei lose their outline; the chromatin of the nuclei appears to become spread out and mixed with protoplasm of the cells, where it is frequently seen as streaks or more or less irregular areas staining a rather bright blue and resembling to a certain extent mucoid degeneration.

The blood-vessels, especially the small ones which are in close relation to the tumor, show marked endarteritis, completely occluding the lumina of the vessels. Around the occluded blood-vessels the breaking-down of tumor cells is decidedly more pronounced than at any other place, even at the periphery of the cell nests. The tumor cells gradually disappear by a process which appears to be some form of cytolysis, which is then followed by their absorption.

It is evident that we have to do here with an agent of extraordinary character; it destroys tumor cells which have power of proliferating, and of infiltrating and destroying surrounding

Fig. 93.—Section from a nodule of carcinoma of the skin. Case 53.

Fig. 94.—Section from the border of a carcinoma ulcer, showing changes produced by *x*-rays. Case 53.

Fig. 95.—Same as Fig. 94, under higher power.

tissues, almost regardless of their nature and structure. It attacks the youngest and most actively proliferating and most destructive cells, while its effect on the normal tissue is of markedly less severity.

The final stage produced in the successful use of *x*-rays in the treatment of carcinoma is shown in microphotograph (Fig. 96). This section is taken from a piece of tissue excised from a healthy scar exactly at the site of the previous carcinoma (see Case 46, Figs. 115 to 117). As will be seen, the carcinomatous tissue has been replaced by a dense layer of healthy connective tissue, whose fibers present a strikingly regular appearance. The surface is covered by a thick layer of healthy epithelium. There are no papillæ remaining. At no place is there the slightest suspicion of carcinomatous infiltration.

The healed edge of a rodent ulcer examined by Sequeira * showed much the same condition that was found in my sections of scar tissue. He reports that it consisted largely of connective tissue. The epithelial cells seemed to have undergone a peculiar change, the nuclei being irregular and the outline of the cells ill defined.†

* Brit. Med. Jour., 1901, i, p. 332.

† The foregoing are the facts as to the pathological changes caused in the tissues by *x*-rays. There has been a good deal of speculation indulged in without the foundation of histological studies, and it may be interesting to consider these theories for a moment.

One of the first explanations offered was that of Kaposi (Wien. med. Presse, 1899, xl, p. 1285), which has been widely quoted on account of his eminence. It was to the effect that "in diseased areas where there is inflammatory infiltration or formation of new tissue, the cellular elements are altered in their molecular structures, and are thus prepared for resorption." Huntington (Annals of Surgery, 1901, xxxiv, p. 808) suggested that the *x*-ray changes in tissues are dependent upon irritation of the peripheral nerves, with secondary paralysis of the vasomotor system. Hopkins (Phila. Med. Jour., 1900, v, p. 808) suggested that they were due to the destruction of the nerve-supply of the exposed tissues, and offered the name white gangrene for the condition (though why white gangrene, rather than yellow, or green, or mauve, is not apparent, as they are all equally inaccurate in their description of the condition). Blackmarr (American Electro-Therapeutic and X-Ray Era, 1901, 1, No. 3, p. 1) suggested that *x*-ray vibrations caused increased vitality in the leucocytes. Sharpe (Archives of the Röntgen Ray, 1901, v, p. 85) and others suggested that they are due to a primary effect upon the capillaries.

The accurate studies which have been made upon the subject are sufficient to show the weak points in these various suggestions. These studies do not show

The findings of different observers thus agree very closely. On first view the findings of Oudin, Barthélemy, and Darier appear to be at variance with the others, in that they report very slight changes in the corium, but this discrepancy disappears when we remember that their experiments were made upon areas of alopecia "unaccompanied by burns." Practically all agree in describing two sorts of changes: first, evidences of peculiar structural changes in the cells themselves; second, certain proliferative changes in the inner coats of the blood-vessels. These, I believe, must be accepted as the characteristic features in the process. It is striking evidence of the uniformity of these changes, and of the thoroughness with which the subject has been studied, that so many independent observers have agreed so closely in emphasizing in their descriptions the same facts. The process is one primarily affecting the tissue cells themselves. There is evidence first of stimulation of cellular activity, and later, if the effect is at all intense, there follows disorganization of the affected cells. The changes occur first and most markedly in the epithelium, and next in the blood-vessels, but it is likely that they develop also, though to a much less degree, in the cells of all the tissues of the affected area. It is to be noted that the changes in the blood-vessels do not precede the changes in the other tissues, but are found later at least than the first changes in the epithelium. The changes in the cells, therefore, are probably not primarily a result of circulatory disturbance, for they

that the nerves are primarily affected, or that any single tissue is affected primarily to the exclusion of any other. The important rôle played by the capillary changes has already been called attention to. Blackmarr's suggestion and Kaposi's suggestion are in line with the effects found, but are hardly definite enough to be of any scientific value. The most far-fetched suggestion is that of Hopkins, that the changes are due to electrical discharges through the tissues; that for this discharge the nerves form the chief conductor; and that they are burned out by an overload of electricity in the same way that electrical wires which are overloaded are burned out. Of course, this suggestion entirely ignores the facts. There is no reason to believe that any induced electricity is discharged through the tissues, but even admitting that there was a discharge of electricity through the tissues, there is nothing to indicate that the nerves would be any better conductors of this than the other tissues. In fact, it is known that they are not, and the pathological findings have shown that the changes in the nerves are not particularly prominent.

Fig. 96.—Section from a scar following the treatment by *x*-rays of a cutaneous carcinoma.

come earlier than, or at least at the same time as, the signs of vascular lesions. Accordingly the changes in the blood-vessels are not the essential cause of *x*-ray injuries, but are probably analogous to those which occur in the other tissues at the same time. It is doubtless true that the changes in the blood-vessels are factors of importance in the later changes that occur in the tissues, but it is not to be lost sight of that they come into play after the cellular disturbances are already well along in their development.

It is an interesting fact that attention has not been called especially to changes in the nerves.

The changes seen in pathological tissues under *x*-ray treatment present the same characteristics as those seen in healthy tissues exposed to *x*-rays. There is first evidence of stimulation of certain intracellular processes, and later degeneration and absorption of the diseased tissues, the whole accompanied by an inflammatory reaction, which first aids in the destruction of the degenerating tissue and then in its replacement with healthy connective tissue. Accompanying the whole process are the characteristic changes in the blood-vessels.*

The especially significant feature is the degeneration and disappearance of pathological tissues under *x*-ray effects which are not sufficiently intense to destroy the healthy stroma. This is evidently the key-note to the use of *x*-rays in the treatment of certain diseases, the morbid products of which must be disposed of in order to get relief; a reaction must be

* Hektoen has suggested in a personal communication to me that the changes in the blood-vessels may be at times partially accounted for by the fact that as the tissues of any area involved shrink under the effect of exposure to *x*-rays, the extent of the territory supplied by the corresponding arteries and veins is diminished. The researches of Thoma have shown that under such conditions there is a new growth of connective tissue in the intima of the blood-vessels, resulting in a compensatory narrowing of the lumina, which thus become adjusted in size to the needs for blood in the parts involved. Perhaps some of the endovascular productive changes seen in tissues exposed to *x*-rays are explainable on the score of this compensatory proliferation described by Thoma. The difficulty, however, in the way of this theory is that these changes in the blood-vessels are seen before there is any shrinkage of the tumor, and before there is any diminution in the vascular needs of the part. Indeed there would seem to be an increased demand for blood in the affected parts, at the very time that these changes in the blood-vessels occur

produced sufficient to cause destruction of the diseased tissues which constitute the pathological process, but not sufficient to destroy the surrounding healthy tissue. As to why these changes are produced in tissues by *x*-rays, the explanation doubtless lies in the fact that tissue cells are susceptible to energy in the form of *x*-rays, and the result of the absorption of this energy by the cells is disarrangement of the normal intracellular structure. If the intensity of the *x*-ray effect is sufficient, this derangement of the intracellular structure goes on to the point of disorganization, and complete disintegration of the cells. If this view is correct,—and in my opinion there is no doubt of its accuracy,—the effect of *x*-rays upon cells is entirely analogous to the effect of *x*-rays or light upon susceptible salts like silver salts, in which the absorption of the *x*-rays causes a complete rearrangement of the molecular structure. This susceptibility to *x*-ray energy is certainly most marked in the epithelial cells. Now, the epithelium is the tissue of the skin which has particularly to do with protecting the subcutaneous tissues against the effects of sunlight, and is accordingly most affected by light rays. It is, therefore, not to be wondered at that epithelium should show a greater susceptibility than other tissues of the skin to the effect of an agent so closely analogous to light rays as are *x*-rays.

This effect of *x*-rays on tissues is shown under suitable conditions in normal tissues, but it occurs most readily in the tissues of diseased conditions such as carcinoma, sarcoma, and tuberculosis. As to why certain diseased tissues, like those of tuberculosis, sarcoma, and carcinoma, show a greater susceptibility to the influence of *x*-rays than normal tissues, the explanation, I believe, is not far to seek. The pathological tissues are made up of relatively unstable cells which readily degenerate and are relatively easily destroyed by any disturbance of nutrition. It is likely, therefore, that such cells would prove more susceptible than normal tissues to an agent like *x*-rays, whose effect so distinctly interferes with the normal processes in the cells.

Whether the above explanations are correct or not makes very little practical difference. The important fact, of which

abundant evidence is given in the microscopic studies that have been made, is that there is a derangement of the structures of the cells brought under the influence of *x*-rays, and that this derangement occurs more readily in certain diseased tissues than in normal tissues, so that to a certain extent the *x*-rays may be said to have a selective effect upon such diseased tissues. These diseased tissues accordingly may under suitable conditions be made to undergo degeneration and absorption and replacement by healthy connective tissue without the destruction of the healthy elements. This from a therapeutic standpoint is the important fact that is gained from a study of tissues affected by *x*-rays; and it is a fact pregnant with possibilities.

CHAPTER III.

THE EFFECT OF X-RAYS ON BACTERIA.

The Effect of X-rays on Bacteria in Cultures.—There is some conflict of statement in the literature concerning the effect of *x*-rays upon bacteria. A number of writers, largely on the basis of clinical experience with *x*-rays in bacterial diseases and without having experimental data for their assumption, have assumed that *x*-rays have decided germicidal properties. And a few observers have reported experiments upon bacteria in cultures, tending to show the existence of positive germicidal properties in *x*-rays themselves. The report upon this subject which has received most consideration is that made by Rieder.* Rieder exposed fresh plate cultures of the cholera vibrio, Bacillus coli communis, Bacillus typhosus, the bacillus of diphtheria, and others, to the effect of *x*-rays for periods varying from forty minutes to an hour. As a control experiment, part of each of these cultures was protected from the effect of *x*-rays by a cover of sheet-lead. He reports that in all cases colonies developed in those portions covered by the lead, while the parts of the cultures exposed to the rays did not grow. The same effect, however, was not produced upon developed colonies of bacteria. These old colonies were not destroyed by the exposures, but there was no further development. The growth of tubercle bacilli was not prevented, but was distinctly inhibited. He excludes the influence of chemical changes in the culture-media in preventing the growth of the cultures, because later he was able to obtain good growth of bacteria in the areas that had been sterilized by *x*-rays, and by other checks he excluded the influence of heat and electrical effects. Rieder † has recently reported a practical repetition of his experiments, and has reaffirmed his findings.

* Münch. med. Wochenschr., 1898, xlv, p. 773.

† Münch. med. Wochenschr., 1902, xlix, p. 402.

Rudis-Jicinsky* has also presented a series of experiments tending to show positive bactericidal properties in *x*-rays. His results are expressed in the following table:

Under X-ray Irradiation.	Media.	
	Acid.	Alkaline.
Bacillus anthracis	Negative.	Negative.
Bacillus tuberculosis, in sputum, destroyed in	48 min.	Negative.
Bacillus tuberculosis, in flask, destroyed in	50 min.	Growth accentuated.
Spirillum choleræ, in flask, destroyed in	51 min.	55 min.
Bacillus diphtheriæ, in flask, destroyed in	46 min.	48 min.
Bacillus typhi abdominalis, in	45 min.	49 min.
Streptococcus	Negative.	Negative.
Staphylococcus	Negative.	Negative.
Micrococcus pyogenes albus	Negative.	40 min.
Micrococcus gonorrheæ, destroyed in	35 min.	40 min.

Thus it will be seen that his results varied from accentuation of growth of Bacillus tuberculosis in alkaline medium to the destruction of the gonococcus in an acid medium in thirty-five minutes.

The above findings of Rieder and Rudis-Jicinsky are not in accord with the preponderance of evidence upon this subject. Many experimenters have worked in this field, and on the whole the evidence is overwhelming that *x*-rays in themselves possess no marked bactericidal properties.

Berton† found that the diphtheria bacillus in bouillon cultures was not influenced, either in growth or virulence, by exposures of sixteen, thirty-two, and sixty-four hours.

Minck‡ found that fresh cultures of typhoid bacillus on agar plate, after an exposure of three hours, at a distance of 10 cm. from the tube, showed when incubated no difference in growth from an unexposed control plate.

Wittlin§ repeated Minck's experiments with Bacillus typhosus, Bacillus diphtheriæ, Staphylococcus aureus, and Vibrio choleræ, and concludes that Röntgen rays have no influence on the growth or life of bacteria.

* N. Y. Med. Jour., 1901, lxxiii, p. 364.

† La Semaine Médicale, 1896, xvi, p. 283.

‡ Münch. med. Wochenschr., 1896, xliii, pp. 101, 202.

§ Centralbl. f. Bakt., 2. Abth., Bd. ii, p. 676.

Blaize and Sambuc * found that three hours' exposure had no effect on Bacillus anthracis.

Bergonié and Mongour † found that they were unable to reduce the virulence of tubercle bacilli by exposing sputum to *x*-rays.

Wolfenden and Forbes-Ross ‡ report that as a result of two years' study of this subject they find it impossible by any ordinary long exposure to high vacuum tubes to kill growths of bacilli or cocci by *x*-rays.

Basset-Smith § found that broth cultures of Bacillus typhosus, Bacillus coli communis, and cholera vibrio were uninfluenced by exposures for fifteen minutes on three successive days with the tube at a distance of six inches. Bacillus pestis was perhaps slightly inhibited in growth.

Lyon, ‖ Delepine,** and Sabrazès and Rivière,†† as a result of their experiments, have come to similar conclusions.

This subject has been gone over recently in a very careful series of experiments by Prof. F. Robert Zeit,‡‡ of the Northwestern University. His experiments were as follows:

"*Experiments.*—(*a*) Bouillon and hydrocele-fluid cultures, in test-tubes, of Bacillus pyocyaneus, prodigiosus, typhosus, anthracis, and diphtheriæ were exposed to Röntgen rays, at a distance of 2 centimeters from the tube, for two, five, ten, twenty, and forty-eight hours, without any effect whatever upon pigment production, growth, motility, or virulence.

"A repetition of Rieder's experiments proved negative.

"(*b*) Suspensions of the same bacteria in agar were plated out. For the glass cover of the plate I substituted a lead plate 5 mm. thick, which had an oval window cut out in the center. The plate was then exposed to the rays with its agar film toward the tube, at a distance of 20 mm., for one-half, one, two, and four hours. When incubated, the exposed

* Compt. rend. Soc. Biol., 1897, Série 10, vol. iv, p. 689.
† Bull. Acad. Méd., 1897, Série 3, vol. xxxviii, p. 66.
‡ Archives of the Röntgen Ray, 1900, v, p. 3.
§ Archives of the Röntgen Ray, 1901, v, p. 47.
‖ Lancet, 1896, i, p. 513. ** Brit. Med. Jour., 1896, i, p. 559.
†† Compt. Rend. Acad., Série c, 1897, cxxiv, p. 979.
‡‡ Jour. Am. Med. Assoc., 1901, xxxvii, p. 1432.

portion of the agar showed just as many colonies as the non-exposed portions.

"(*c*) A serum plate was smeared thickly with sputum containing from 50 to 100 tubercular bacilli to the field. The plate was exposed without cover for six hours to the rays, at a distance of 20 mm. from the tube. Three guinea-pigs were inoculated, of which one died in five weeks and one in seven weeks of acute miliary tuberculosis. One is alive yet, but is tubercular. It has enlarged inguinal glands, constantly elevated temperature, and has continually lost in weight."

His conclusions are as follows:

"Bouillon and hydrocele-fluid cultures in test-tubes, of non-resistant forms of bacteria, could not be killed by Röntgen rays after forty-eight hours' exposure at a distance of 20 mm. from the tube.

"Suspensions of bacteria in agar plates exposed for four hours to the rays, according to Rieder's plan, were not killed.

"Tubercular sputum exposed to the Röntgen rays for six hours at a distance of 20 mm. from the tube caused acute miliary tuberculosis of all the guinea-pigs inoculated with it.

"Röntgen rays have no direct bactericidal properties."*

* Zeit has also experimented upon the effect of direct, alternating, and Tesla or high frequency and high potential currents upon bacteria, and on the effect of a magnetic field upon bacteria. These experiments are not quite pertinent to the question that we have under discussion, but the effects of electricity are so confused with those of *x*-rays in many minds that I venture to quote here his conclusions from these experiments.

"1. A continuous current of 260 to 320 milliamperes, passed through bouillon cultures, kills bacteria of low thermal death-points, in ten minutes, by the production of heat—98.5° C. The antiseptics produced by electrolysis during this time are not sufficient to prevent growth of even non-spore-bearing bacteria. The effect is a purely physical one.

"2. A continuous current of 48 milliamperes passed through bouillon cultures for from two to three hours does not kill even non-resistant forms of bacteria. The temperature produced by such a current does not rise above 37° C., and the electrolytic products are antiseptic but not germicidal.

"3. A continuous current of 100 milliamperes passed through bouillon cultures for seventy-five minutes kills all non-resistant forms of bacteria, even if the temperature is artificially kept below 37° C. The effect is due to the formation of germicidal electrolytic products in the culture. Anthrax spores are

In the light of these findings from so many observers working independently, the conviction cannot be escaped that the influence of *x*-rays *per se* upon bacteria is practically *nil*. It may be true that very long exposures, with great quantities of light, produce an appreciable influence upon bacteria, but this destructive effect upon bacteria is so infinitesimal compared with the effect upon highly organized animal tissues that it may be regarded as *nil*, and for all practical purposes might as well not exist. This fact is not difficult to reconcile with the striking effect of *x*-rays upon highly organized animal tissues. In bacteria we have vegetable organisms of the highest power of resistance, and when we remember how much greater relatively is their power of resistance to heat and cold and other destructive agents than that which is possessed by animal tissues, it is not surprising that they show so strong a power of resistance to the influence of *x*-rays. To express

killed in two hours. Subtilis spores were still alive after the current was passed for three hours.

"4. A continuous current passed through bouillon cultures of bacteria produces a strongly acid reaction at the positive pole, due to the liberation of chlorine, which combines with oxygen to form HCl. The strongly alkaline reaction of the bouillon culture at the negative pole is due to the formation of sodium hydroxide and the liberation of hydrogen in gas bubbles. With a current of 100 milliamperes for two hours, it required 8.82 milligrams of H_2SO_4 to neutralize 1 cc. of the culture fluid at the negative pole, and all the most resistant forms of bacteria were destroyed at the positive pole, including anthrax and subtilis spores. At the negative pole anthrax spores were killed also, but subtilis spores remained alive for four hours.

"5. The continuous current alone, by means of du Bois Reymond's method of non-polarizing electrodes, and exclusion of chemical effects by ions in Kruger's sense, is neither bactericidal nor antiseptic. The apparent antiseptic effect on suspensions of bacteria is due to electric osmose. The continuous electric current has no bactericidal nor antiseptic properties, but can destroy bacteria only by its physical effects (heat) or chemical effects (the production of bactericidal substances by electrolysis).

"6. A magnetic field, either within a helix of wire or between the poles of a powerful electro-magnet, has no antiseptic or bactericidal effects whatever.

"7. Alternating currents of a 3-inch Ruhmkorff coil, passed through bouillon cultures for ten hours, favor growth and pigment production.

"8. High frequency, high potential currents—Tesla currents—have neither antiseptic nor bactericidal properties when passed around a bacterial suspension within a solenoid. When exposed to the brush discharges, ozone is produced and kills the bacteria."

it in another form, there is nothing inconsistent between the pronounced effect of *x*-rays upon susceptible animal tissues, and the practical absence of effect of *x*-rays upon resistant vegetable organisms of the lowest forms.

As has been suggested by Freund,* the destruction of bacteria in cultures by exposures to *x*-rays may be due to the electrical discharges, and in the light of other experiments it is probable that such an explanation must be sought to account for the results of Rieder's and Rudis-Jicinsky's experiments.

Effect of X-rays on Bacteria in Living Tissues.—The behavior of bacteria in living tissues under the influence of *x*-rays is quite different from that when they are growing in inert media. When a suppurating ulcer is exposed to a sufficient extent to *x*-ray influence, unmistakable evidence of interference with the growth of the pus organisms is shown. The discharge changes from pus to a sero-purulent and then to a sero-fibrinous fluid, and soon the ulcer becomes clean and free from evidence of contamination with pus organisms. This drying-up and cleaning of infected ulcers has been noted by numerous observers. Attention has been called to it by Startin † in lupus, Greenleaf ‡ in lupus, Sequeira § in rodent ulcer, Eijkman ‖ in carcinoma, and many others. It occurs regardless of the character of the ulcer. I have repeatedly seen dirty, septic ulcers of carcinoma, syphilis, and lupus become clean and sterile under the influence of *x*-rays alone without the use of antiseptics; at times, indeed, under conditions most unfavorable for the maintenance of cleanliness. This inhibition of the formation of pus and checking of septic processes under the influence of *x*-rays is shown best in diseases of the skin which are essentially due to infection with the ordinary pyogenic organisms. Case 15, page 351, of sycosis, illustrates well this property of *x*-rays. This was a case of sycosis due to simple pus infection without contamination by the ringworm fungus,

* Sitzungsberichten kaiserl. Akad. der Wissenchaften in Wien. Math.-naturwissens. Classe, Bd. cix, Abth. ii, Oct., 1900.

† Lancet, London, 1901, ii, p. 144.

‡ Buffalo Med. Jour., 1901, xli, p. 189.

§ Brit. Med. Jour., 1901, ii, p. 851.

‖ Krebs und Röntgenstrahlen, 1902, Haarlem.

and it had resisted irritating antiseptic treatment for several months. At the time that the *x*-ray exposures were begun the hair follicles were freely discharging pus, which was full of common pyogenic organisms. Under *x*-ray exposures alone the condition entirely cleared up; the septic process was stopped and the bacteria in the tissue entirely disappeared. The literature is full of similar cases. The inference is positive, from the clinical behavior of such septic processes, that the ordinary pyogenic organisms, when situated in superficial tissues, are destroyed under the influence of *x*-rays.

Similar germicidal effect of *x*-rays upon mycelial fungi is shown in the results in the treatment of tinea barbæ, tinea tonsurans, and favus, which have been reported by several observers. The cure of lupus under *x*-rays also, and the result in several other bacterial diseases, indicate the effect of *x*-rays upon a number of other pathogenic organisms. As showing the effect of *x*-rays on tubercle bacilli, the experiments of Lortet and Genoud * are of interest. They inoculated in the inguinal region eight guinea-pigs of the same size and weight with material from the spleen of a tuberculous guinea-pig. Of these eight, three were chosen at random and given exposures daily over the inguinal regions. The three remained well, showing only small nodules at the points of injection, which gradually disappeared, while in the five unexposed pigs tuberculous ulcers resulted at the points of inoculation and the pigs became thin.

The fact that organisms in living tissues can be destroyed by exposure to *x*-rays, while the same organisms in inert cultures are uninfluenced by *x*-ray exposures, proves positively that it is not the influence of *x*-rays *per se* that causes the destruction, but that the tissues themselves, doubtless under conditions of activity excited by the *x*-rays, play the important rôle in the germicidal process. It may well be imagined that this process is in the nature of stimulation of the cells, which are rendered thereby better able to take care of the invasion of the organisms. That the effect on bacteria is caused by increased phagocytosis has been suggested by Blaise and

* Semaine Médicale, 1896, xvi, p. 266.

Sambuc,* Bergonié and Mongour,† Basset-Smith,‡ Ullman,§ and various other writers.

Whether these destructive effects upon micro-organisms may be produced deep in the tissues or not, is as yet uncertain. It is the same question in another form as the effect of *x*-rays upon deep-seated tissues. If sufficient reaction upon the deeper tissues can be produced, it is certainly true that the same effect upon bacteria will occur that is seen in bacteria nearer the surface. The evidence now at hand points rather against very marked effect upon bacteria deeply situated in the tissues. Inoculation experiments by Scholtz‖ and Mühsam ** are of some value in this connection. From his experiments Scholtz concluded that *x*-rays have no effect in preventing inoculation tuberculosis in guinea-pigs. Mühsam concluded from his experiments on guinea-pigs that *x*-rays exercise no influence on general tuberculosis, but that they restrain local tuberculosis to a point where its action is very slight. On the other hand, Ausset and Bédart †† have reported tubercular peritonitis cured under *x*-ray exposures.

* Compt. rend. Soc. Biol., 10 Série, vol. iv, 1897, p. 689.
† Bull. Acad. Méd., 1897, 3 Série, vol. xxxviii, p. 66.
‡ Archives of the Röntgen Ray, 1901, v, p. 47.
§ Wien. med. Presse, 1900, xli, p. 954.
‖ Arch. f. Derm. u. Syph., 1902, lix, p. 78.
** Deutsch. med. Wochenschr., 1898, xxiv, p. 715.
†† Echo Médicale du Nord, 1899, iii, p. 604.

CHAPTER IV.

THE CAUSES OF THE PHENOMENA OBSERVED IN TISSUES AFTER EXPOSURE TO X-RAYS.

What is the Active Agent in the Production of the Tissue Changes following X-ray Exposures?—Since the occurrence of the first *x*-ray burns this has been a question that has given rise to much speculation. In the early days of *x*-rays there was a tendency to attribute *x*-ray burns not to *x*-rays themselves, but to some accompanying factor the exclusion of which would prevent the occurrence of *x*-ray burns. It was suggested that they might be due to particles of matter from the cathode or anticathode driven into the tissues; again, that heat was a factor in their production; again, that they were due to chemical compounds formed around the tube; again, that they were due to bacteria driven into the tissues; again, that they were due to ultra-violet rays; and, finally, the theory was suggested, and has been very tenaciously held, that the effects on the tissues were electrical and not due to *x*-rays. Tesla * suggested as an explanation of *x*-ray injuries, the possibility of cathodic matter at a high temperature being driven into the tissues by *x*-rays and also the possibility of their being due to ozone generated around the tube, or other chemical compounds. That the injuries were due to bacteria driven into the tissues has been suggested by several writers. That these changes are of electrical origin has been suggested by Leonard,† Schiff,‡ and Freund.§ That the phenomena are due to *x*-rays themselves has been urged very strongly from the beginning by various observers: Elihu Thomson,‖ Jones,**

* Electrical Review, 1897, xxx, p. 207.

† American X-ray Journal, 1898, iii, p. 453.

‡ Wien. med. Presse, 1902, xliii, p. 1025.

§ Klin. therap. Wochenschr., 1901, No. 1, 2.

‖ Boston Med. and Surg. Jour., 1896, cxxxv, p. 610. American X-ray Journal, 1898, iii, p. 451, and 1899, iv, p. 494.

** Phila. Med. Jour. 1900, v, p. 63.

Scholtz,* Kienböck,† and many others. Many of these suggestions have been simply speculation without the support of experimental or other conclusive data.

The experiments of Elihu Thomson, to be referred to later in this connection, conclusively establish, I believe, the fact that none of these factors plays an important rôle except the *x*-rays themselves. Before taking up Thomson's experiments, it may be worth while briefly to consider other facts bearing upon this question.

In the first place, the histological findings offer strong corroborative evidence in favor of the theory that the changes in the tissues are due to a form of energy of high actinic power to which the tissue cells are susceptible. The histological changes are not those of a simple destructive process or an ordinary inflammation, such as would be due to heat or to the presence of foreign bodies in the tissues or chemical caustics or ordinary infection. Great primary increase in the pigment in the skin and thickening of the layers of the epidermis, primary atrophy of the gland structures, numerous karyokinetic figures, the breaking up of cell nuclei before the breaking up of the cells themselves, peculiar degeneration in the embryonic epithelium of malignant growths—these are not the changes that one sees in an ordinary inflammatory process.

As to the possibility of *x*-ray injuries being due to ozone or other chemical compounds formed around the tube, their presence in sufficient quantity to account for the changes does not occur. In favor of the ozone theory Lilienthal ‡ called attention to the blanching of the hairs, suggestive of ozone, but the hairs under the effects of *x*-rays become white, and they never resemble the yellow bleaching of the hairs produced by ozone.

To determine the question of the presence of particles of platinum driven off from the anticathode, Gilchrist § submitted a piece of tissue from an *x*-ray burn to Professor Abel, of Johns

* Arch. f. Derm. u. Syph., 1902, lix, p. 87.

† Wien. klin. Wochenschr., 1900, xiii, p. 1153. Interstate Medical Journal 1902, ix, pp. 1, 60.

‡ Medical Record, 1897, li, p. 287.

§ Johns Hopkins Hosp. Bull., 1897, viii, p. 17.

Hopkins University, and on minute chemical examination he discovered no platinum.

As to the theory that these burns are due to the driving in of bacteria, no facts have ever been brought to its support, except the statement that *x*-ray burns occur more readily upon surfaces that are dirty. I have already called attention to the fact that in my experience this is not the case. I have made careful observations upon this point, and in long experience I have not found that cleanliness or lack of cleanliness of the surface exposed to *x*-rays is a factor of any importance in the production of *x*-ray burns. To overcome this supposed factor of bacteria in producing *x*-ray burns, it was suggested that the surface to be exposed be covered with vaselin, so that the entrance of the bacteria, and the resultant injury, should be prevented. Later, paraffin has been suggested. Very many observations upon surfaces protected by vaselin have shown in my experience that vaselin furnishes no protection whatever. I have similarly protected a surface in one case very carefully by a layer of paraffin $\frac{1}{16}$ of an inch thick. This surface was in addition kept scrupulously clean; nevertheless *x*-ray dermatitis developed as promptly as under other circumstances. The interposition, also, of a layer of aluminum has not interfered with the production of *x*-ray burns. Indeed, I am willing to state dogmatically that the interposition of no substance through which *x*-rays can penetrate in sufficient quantities to produce a photograph will prevent the production of *x*-ray dermatitis. In other words, nothing that does not prevent the passage of *x*-rays themselves will prevent *x*-ray dermatitis.

The experiments of Prof. Elihu Thomson * upon this point are worthy of detailed account. His first experiment was upon the little finger of his left hand, which he exposed to *x*-rays from a tube of peculiar construction, at a distance of about $1\frac{1}{4}$ inches from the target for one-half hour. This was followed by a severe *x*-ray burn, which first began to develop nine days after exposure. He makes the following comments upon the experiment: "I am willing to admit that ultra-violet

* Boston Med. and Surg. Jour., 1896, cxxxv, p. 610.

rays might possibly, if they existed in large quantities, produce some such effect, but I am not willing to admit that brush discharges had anything to do with it, for the simple reason that the potential used was too low, being produced from a small 24-plate static machine, and there were no perceptible sparks from the tube to the finger. I am strongly of the opinion that it is really an *x*-ray effect, and that neither ultra-violet rays nor brush discharges have anything to do with it. I have worked with the brush discharges around electrical apparatus when I know the sum total of effect must have been many times what could possibly have been obtained in this case, assuming that they existed here imperceptibly. I worked in the dark and saw and felt none. As to the ultra-violet rays, I am convinced that they are not responsible for the results, chiefly because of the effect being continued laterally, on each side of the finger, a portion not exposed to ultra-violet rays under the conditions unless they traversed a considerable thickness of the dermal layer, filled with blood-vessels which would absorb the rays. The rays, whatever they were, came from the bombarded spot, and were limited to the area which Röntgen rays could reach. The tube was a blue glass tube with a clear German glass window of about $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in diameter beside the bombarded spot. The fingers opposite the blue glass were not affected, as this is so dense as to absorb the Röntgen rays. Only where the little finger was opposite the clear glass was it affected, and there is a sharp line of demarcation between that portion of the finger and the portion back of the blue glass. I think the blue or purplish glass would have been transparent to ultra-violet rays, but not to Röntgen rays. There is only the supposition left that the effect was produced by Röntgen rays or something that comes with Röntgen rays."

Upon this same point Thomson * has offered further experiments. To dispose of the theory that *x*-ray injuries are due to electro-static discharges, he repeated the experiment of exposing a finger to *x*-rays, using for it the adjoining finger to the little finger upon which the experiment above described

* American X-ray Journal, 1898, iii, p. 451.

was performed. The experiment was as follows: "The adjoining finger (the fourth finger of the left hand) was protected by sheet-lead which had a window cut in it so as to limit the effect of possible burns to a small elongated spot. This window in the sheet-lead was divided by a strip of tinfoil lying close to the finger, and in one of the divisions so made the finger was covered by a double layer of aluminum foil, the other division being left bare. An exposure for a short time was followed by two small burns, one on the part which had been under the aluminum foil, the other on the bare spot. It is inconceivable that any electro-static effect should have acted through the aluminum alone more than through the tinfoil, or more than through the sheet-lead, as all three of these metal layers were in electrical contact and subjected to the same conditions. Electro-static effect or electric discharges were plainly ruled out. These results should have settled the question of ozone, chemical effects, electro-static discharges, etc."

The writer has carried out similar experiments on guinea-pigs as follows: The guinea-pig was laid upon a sheet of lead; the anterior third of the trunk and head were protected from *x*-rays by a sheet of lead $\frac{1}{32}$ of an inch thick. The rest of the trunk was covered by a sheet of aluminum $\frac{1}{50}$ of an inch thick. All three sheets were in electrical contact with each other, and all were grounded by a wire having a water connection. The conditions therefore were such as entirely to exclude any electrical effects, and also to protect the guinea-pig from any rays that would not penetrate aluminum or lead. The guinea-pig was exposed to a fairly strong light with the target at a distance of five inches, for an hour and a half. In ten days the hair on the surface which was covered by aluminum came out, and an *x*-ray burn developed. The surface protected by the lead was entirely unaffected. A repetition of the experiment upon another guinea-pig gave the same result.

In this experiment the conditions were such that electrical effects and ultra-violet light were plainly thrown out. The entire surface was covered by aluminum or lead, which were grounded, thus throwing out of consideration entirely induced

electrical currents, brush discharges, or any effects in the static field. The entire guinea-pig was covered with aluminum or lead, both of which are opaque to ultra-violet rays, thus excluding them. The only conclusion that can be drawn from this experiment, as from Thomson's, is that the effect could be due to nothing else except rays of energy coming from the *x*-ray tube, which were able to penetrate aluminum and not lead, and the only form of energy having these qualities which could come under consideration in this connection is *x*-rays. The experiment is mathematically conclusive, and leaves no qualification to be made in the statement that *x*-ray burns can be produced by *x*-rays themselves.

This fact does not in any way conflict with the fact that similar effects may be produced by high tension currents without *x*-rays. Schiff and Freund * have called attention to their experiments proving that an effect similar to *x*-ray effect can be produced in a rabbit by direct discharge from an induction coil, and Rollins † has reported an experiment in which he exposed his hand to the action of an *x*-ray tube, the resistance of which was so high that no current could pass through, yet some days later dermatitis appeared on the surface. He thinks that this proves conclusively that burns can be produced by the action of induced electricity around the tube, but he very justly adds that it does not affect the proposition that *x*-rays themselves can cause burns. It may be readily admitted that burns similar to *x*-ray burns may be produced by electrical discharges; indeed, it would be expected *a priori* that such effects might be produced; but that does not in any way affect the fact that they may also be produced by *x*-rays. That the usual burns produced in *x*-ray exposures are not due to electrical discharges is shown by the fact that when lead plates are used to protect the surrounding surfaces the burn is sharply limited to the part not covered by lead. I have had innumerable opportunities to observe this fact, and I have never seen an *x*-ray burn extend beyond the line which was unprotected by lead. It has never been my practice to ground the lead

* Klin. therap. Wochenschr., 1901, Nos. 1, 2.

† Electrical Review, 1898, xxxii, p. 12.

mask, and the fact that the effect upon the tissues is always sharply limited to the surface which the *x*-rays reach, and does not appear on the surface covered by lead, which would not in any way interfere with effects in the electro-static field, shows conclusively that the electrical effects play a part of no practical importance in the production of these burns. So uniform has been my experience in this connection that I have no hesitation in making the statement without qualification that a lead plate $\frac{1}{16}$ of an inch thick will absolutely prevent the development of any burn beneath it. One-sixteenth inch plate is specified because Röntgen states that lead of that thickness is entirely opaque to *x*-rays. As a matter of fact, a lead plate $\frac{1}{32}$ of an inch thick furnishes ample protection against *x*-ray burns.

What is the Property in X-rays that Affects Tissues?—Accepting, then, as we must, that the changes in tissues produced under *x*-ray exposures are due to the *x*-rays themselves, what is the property in *x*-rays that causes these changes? A little consideration of the subject, I believe, leads inevitably to the conclusion that it is actinic properties of *x*-rays which are identical with or very closely analogous to the actinic properties of light. A consideration of the analogous properties of *x*-rays and light is instructive in this connection.

It is the accepted view among physicists to-day that *x*-rays are a form of radiant energy transmitted through the ether of the same character as light. To quote Professor Barker,* of the University of Pennsylvania: "Röntgen himself at first was favorably inclined to the idea that they (Röntgen rays) were waves due to longitudinal vibrations in the ether. But later he was convinced that they were essentially identical with light waves—that is, with transverse waves in the ether." The obstacles in the way of accepting the theory that *x*-rays were transverse waves in the ether were largely due to the fact that they did not act in the same way as light waves, as regards reflection, refraction, and diffraction. These obstacles were overcome by the idea which was suggested about the

* Preface to "Röntgen Rays," edited by Barker, Harper Bros., New York, 1899.

same time by Professor Stokes, of Cambridge, Professor J. J. Thompson, of Cambridge, and Professor Lehman, of Karlsruhe, that *x*-rays are due to quite irregular pulses and their phenomena are quite different on that account from those of regular trains of waves, like light. This idea was very beautifully set forth by Professor Stokes in the Wilde Lecture.* He says: "According to the theory of the nature of the Röntgen rays which I have endeavored very briefly to bring before you, we have here, as I think, a system various parts of which fit into one another. You start with Röntgen rays, which consist, as I conceive, of an enormous succession of independent pulses; you pass to the Becquerel rays,† which are still irregular, but are beginning to have a certain amount of regularity, and you end with the rays which constitute ordinary light. According to this theory, the absence of diffraction in the Röntgen ray is explained, not by supposing they are rays of light of excessively short wave length, but by supposing they are due to an irregular repetition of isolated and independent disturbances."

X-rays, then, and light rays are transverse vibrations of the ether of essentially identical character, differing only in unessential variations in the quality of the waves. This conception entirely disposes of the difficulties in the way of the theory that *x*-rays and light rays are modes of motion of the ether of essentially the same character.

The physical resemblance between *x*-rays and light is very close. *X*-rays are by no means all of one character, but consist of "a mixture of rays which are absorbed in different degrees and which have different intensities." ‡ It is agreed that *x*-rays vary in their property of affecting tissues. In these respects

* "Röntgen Rays," Barker, p. 63.

† In considering the relationship of *x*-rays, Becquerel rays, and light, it is interesting to note that effects on tissues similar to those produced by *x*-rays have been produced by Becquerel rays. Becquerel (Compt. rend. Acad. Sci., 1901, cxxxii, p. 1289) produced an ulcer on his own person by wearing a small flask of radium near the skin. Danlos (Annales de Derm. u. Syph., 1902, 4e Série, iii, p. 723) has reported cures of lupus by exposures to Becquerel rays, the results being entirely similar to those produced by *x*-rays. Such results as the above furnish the strongest possible evidence of the essential relationship between these different forms of energy.

‡ Röntgen's third article, "Röntgen Rays," Barker, p. 35.

the analogy to light is as close as possible. Light consists of a mixture of rays, extending from the rays beyond the red to those beyond the violet, and these differ in their actinic properties, from the rays at the red end of the spectrum, which practically have no actinic properties, to the highly actinic rays at the violet end of the spectrum.

X-rays and light rays have the common property of causing fluorescence in certain substances. An interesting analogy in the way of fluorescence exists between the ultra-violet rays which are invisible and the *x*-rays which are also invisible. Invisible ultra-violet rays are converted into visible blue rays on impinging upon the surface of quinin in solution,* and Röntgen rays are converted into visible greenish rays on impinging upon the surface of barium platino-cyanide. In other words, both *x*-rays and ultra-violet rays are convertible into visible light rays.

As is well known, the active properties of light and of *x*-rays, as shown in their action upon silver salts, are the same. So exactly are they identical that the methods of photography with light are used with *x*-rays, without variation either in the preparation of the plates or their development after exposure. The action of the one upon the silver salts is identical with that of the other. This subject has been carefully studied by A. and L. Lumière † and by Hansmann.‡ They agree that the chemical changes in photographic emulsions produced by light and those produced by *x*-rays are identical.

As we have already seen, the effects of light, as shown by sunburn, and of *x*-rays, as shown by *x*-ray burns of mild intensity, are indistinguishable in appearance. There is the same tanning and the same redness in *x*-ray dermatitis as in sunburn. And as Finsen has shown, light burns also have a period of incubation extending over one or two days. How close the clinical resemblance is between sunburn and mild *x*-ray burns has been shown when considering *x*-ray burns.§

* "Radiography," Bottone, Whittaker & Co., London, 1898, p. 160.

† Compt. rend. Acad. Sci., 1896, cxxii, p. 382.

‡ Fortschr. a. d. Geb. der Röntgenstrahlen, 1902, v, p. 89.

§ In comparing the effect of *x*-rays and light upon the skin, it is interesting to consider some of Finsen's experiments upon the subject. He exposed the flexor

But outside of all other considerations we have one fact in the effect of *x*-rays upon the organs of sight which is the strongest possible presumptive evidence that *x*-rays are a form of energy of the closest similarity in character to light; and that is the fact that *x*-rays can produce a light sensation upon the retina. The statement of Professor Röntgen * upon this highly interesting point is as follows: "The fact observed by Herr G. Brandes, that the *x*-rays can produce a light sensation on the retina of the eye, I have found confirmed. There stands also in my observation journal a note at the beginning of the month of November, 1895, according to which I perceived a feeble light sensation, which spread over the whole field of vision, when I was in an entirely darkened room, near a wooden door on the other side of which there was a Hittorf tube, whenever discharges were sent through the tube. Since I observed this phenomenon only once, I thought it a subjective one, and the fact that I never saw it repeated is because later, instead of a Hittorf tube, other apparatus was used,

surface of the forearm for twenty minutes to a very powerful electric arc light (80-ampere light) at 50 to 75 cm. distance. There occurred an inflammation of the skin which he describes as follows:

"The inflammation thus incited differs from any other kind of inflammation of the same extent, inasmuch as it was followed by a marked pigmentation of the skin of several months' duration.

"It does not appear at once, as does a burn, but has its maximum in one or two days after exposure.

"It appears only on those parts of the skin which have been directly exposed to the light, while heat rays are also capable of acting through the clothing."

Several months afterward all traces of the burn had disappeared. Finsen was able to demonstrate that the skin still showed traces of the effect of light, in that parts which had been protected remained almost white on rubbing, while the parts which had been exposed to the light were markedly flushed. He adds that this can be explained only by assuming that the action of the chemical rays had caused a more or less permanent dilatation of the capillaries and smaller arterioles of the skin.

It is thus seen that experimental inflammations of the skin produced by exposures to light show effects strikingly analogous to those of *x*-rays. The macroscopic changes are similar, there is a period of incubation, and the effects persist for a long time. . . . . Abstract from Clemensen's report of Finsen's article, "Nye Undersoegelser over Lysets Indvirkning paa Huden." Meddelelser fra Finsen's Medicinske Lyssinstitut, January, 1900, pp. 17-18; Chicago Medical Recorder, 1902, xxiii, p. 195.

* "Röntgen Rays," Barker, p. 39.

not exhausted so much and not provided with platinum anodes. On account of their state of high exhaustion, Hittorf tubes furnish rays which are only slightly absorbed; and on account of the presence of a platinum anode, which is struck by the cathode rays, they furnish intense rays, a condition which is favorable to the production of the light phenomenon referred to. I was obliged to replace the Hittorf tubes by others, because after a very short while all were perforated. With the hard tubes now in general use the experiment of Brandes may be easily repeated."

This demonstration that *x*-rays will produce upon the organs of sight a light sensation is of the highest possible significance in arriving at an interpretation of the effect of *x*-rays upon living cells. To put it in other words, it means that *x*-rays have the property of influencing, as though they were light rays, the organs which have been especially adapted to the reception of impressions from the form of energy which we know as light. Stronger evidence could hardly be found that the effects of *x*-rays and of light rays upon living cells are as close as possible.

We have, then, the following facts: *x*-rays and light are forms of vibration of the ether of the same kind. *X*-rays and the highly actinic ultra-violet rays, both of which are invisible, are both capable of producing fluorescence in certain substances, and thus being converted into visible light rays. The actions of light and of *x*-rays upon salts sensitive to light are the same; the actions of light and of *x*-rays upon the skin and subcutaneous tissues are the same; and, finally, *x*-rays produce upon the retina a sensation of light.

The resemblances, therefore, between *x*-rays and light are as close as possible, and the inference could not be more direct that the property in *x*-rays which causes effects upon silver salts and upon tissues is identical with, or as closely analogous as possible to, the property in light which causes the same effects upon silver salts and upon living tissues. Now, it is universally accepted that the effect of light upon salts which are susceptible to light, as certain silver salts, and upon the skin, is attributable to the actinic properties of light. It

seems impossible, then, to avoid the conclusion that the effect of *x*-rays upon the same salts and upon living tissues is due to the actinic properties of *x*-rays. In other words, the property of *x*-rays that causes reduction of silver salts in a photographic emulsion is the same property which causes the effect upon living tissues.

And this labored analysis of the question leads us to the same conclusion that, it would seem, would be most natural upon first glance. For, without analysis, it would seem reasonable to conclude that the property of *x*-rays that causes rearrangement of the molecules of a silver salt and the formation of a new compound is the same that affects the cellular mechanism of a tissue cell and causes rearrangement of the intracellular structure.

The proposition that the effects of *x*-rays upon tissues are due to their actinic properties, just as the effects of light rays upon tissues are due to their actinic properties, does not carry with it the corollary that the actinic properties of light and of *x*-rays are identical. The actinic properties of the two are very strikingly analogous; they may be identical, but that they are identical in every respect is not proved, and is not a necessary inference from their similar qualities. And, on the other hand, the establishment of certain dissimilar qualities does not in any way destroy the force of the analogy. They may have certain characteristics quite dissimilar, without interfering with the inference that they are in their essential nature the same, just as the fact that *x*-rays cannot be diffracted, reflected, or refracted, offers no obstacle to the theory that *x*-rays and light are forms of energy of essentially the same nature.

What are the processes set in motion in the living cells when they are changed by *x*-rays or light? That question no man can answer now, nor ever can until we know what the changes are in the cell that constitute life. As to how *x*-rays or light may act to cause these processes to be set in motion, a theoretical answer to that question is not difficult to formulate. P. M. Jones,* of San Francisco, has stated it very clearly as follows:

* Phila. Med. Jour., 1900, v, p. 63.

"The treatment of lupus by exposures to *x*-rays is akin to the treatment by exposures to ultra-violet light (Finsen), and to the treatment by exposure to concentrated light (Abrams). In each case the action seems to be a simple one, and the explanation not far to seek. The pathologic tissue is largely composed of very complex and unstable molecules, which collectively make up the cell-structure of the lesion. As we know, comparatively little energy is required to upset these complex molecules and cause a rearrangement of their atoms, thus producing a very different cell, with a consequent modification of the cell, if not its actual death. In the action of sunlight upon the skin (burn, tan, freckles, etc.) we have excellent illustrations of capability of radiant energy to produce these chemical rearrangements. As the rays from a soft tube, which are more easily absorbed by the skin, or any body first encountered, than are those from a 'hard' tube, are found to produce the so-called dermatitis Röntgenii more readily than the rays from a hard tube, so they are more efficacious in the treatment of lupus. It is simply that such rays of comparatively long wave length are absorbed and part with their radiant energy, while rays of shorter wave length, less readily absorbed, do not to any great extent affect the chemical arrangement of the cells in the superficial tissues. I believe, for the reasons just given, that the method of treatment by ultra-violet light (Finsen) will be found to be quicker and better than the treatment by *x*-rays. In comparison with the *x*-rays the ultra-violet rays from an arc light have a very long wave length, and hence will part with all their energy through absorption by the molecules of the superficial cells. The action is a purely mechanical one, a transfer of energy by wave motion (radiant energy), and is typically illustrated by the change which occurs in the photographic emulsion when exposed to light."

Several objections have been offered to the idea that the effects of *x*-rays and of light on tissues are of the same character. In the first place, while the lesser degrees of *x*-ray burns are like sunburn, light does not cause destructive lesions like the severe *x*-ray burns. This may be explained upon several suppositions: In the first place, the tissues may be more sus-

ceptible to the actinic properties of *x*-rays than to those of light. Or, to express it in other words, the actinic properties, as respects living cells, of a given quantity of energy in the form of *x*-rays may be greater than of an equal quantity of energy in the form of light rays. Or it may be that the actinic energy in the *x*-rays that can be projected from a powerfully energized tube upon a given surface is greater in quantity that can be obtained from the amount of light that it is practicable to focus upon any part of the body. It is possible that both of these factors play a part. To consider the second point first, it is possible that if we concentrated a sufficient quantity of light upon a given area, effects quite equal in severity to those of a severe *x*-ray burn might be produced. And as regards the first point there is nothing difficult in supposing that the actinic properties of *x*-rays are more powerful than those of any of the rays of light. The different rays of light themselves vary in their actinic properties, from the red and ultra-red rays with almost no actinic properties, to the highly actinic rays at the violet end of the spectrum. If light rays vary so much among themselves, as regards the intensity of their actinic properties, is it hard to imagine that there might be a variation in the same respect between light rays and *x*-rays?

Again, the absence of deep destructive processes from sunburn may be explained by the lesser penetration of light rays. That light rays can destroy living tissue is proved when the epidermis is destroyed in sunburn, and it is entirely logical to suppose that could they penetrate the tissues in sufficient quantities, they might exert a similar destructive influence upon deeper tissues.

Another reason offered for not accepting the opinion that actinic properties of *x*-rays similar to the active properties of light are the explanation of *x*-ray effects on tissues, is the difference in the effect of *x*-rays and of light upon bacteria. It must be accepted that *x*-rays have less germicidal power than has ultra-violet light.

Numerous articles have been published upon the question of the effect of light upon bacteria. Their general tenor is to the effect that light has a distinct inhibitory effect upon the

growth of bacteria, but that this effect varies in different bacteria, under different conditions of growth, and under various other circumstances. Most of the experiments which have been made have not been conducted under sufficiently exact conditions to give their conclusions great weight. In the words of Dr. Bang, of the Finsen Laboratories: "The results obtained by different investigators do not compare with the amount of work done. . . . One gets the impression from most of these researches that they have been done by more or less skilful bacteriologists, but by very poor physicists."

Perhaps the most exact experiments which have been made are those by Downes and Blunt, and by Finsen and his associates. Downes and Blunt * conclude from their investigation that light is inimical to the growth of bacteria, and under favorable circumstances wholly prevents it. This action is nearly confined to the light at the blue end of the spectrum. If the germicidal properties of light be represented graphically by a curve, the high point occurs at the violet end of the spectrum, sinking rapidly between the blue and the green, there being still some effect produced by the red rays. They made a very important additional observation that this effect of light is in proportion to the amount of free oxygen in the culture-medium. Experiments with organisms in tubes from which the oxygen had been exhausted showed no difference in growth between the control tubes and those exposed to light. This would seem to indicate that the effect here is not that of light *per se*, and offers some analogy to the fact that *x*-rays have no effect upon bacteria in cultures, but a decided effect upon bacteria in living tissues.

Larsen, in the publications of the Finsen Institute,† has found, first: "That different bacteria are differently affected by light, and that there is considerable difference in the resistance of even closely related varieties"; and, second: "That the time which light requires to kill certain species of bacteria bears no constant relation to that needed to impair their growth."

Buchner ‡ has made experiments upon numerous bacilli:

* Proceedings of the Royal Society, 1896, vol. xxviii, p. 199.

† Quoted by Clemensen, Chicago Medical Recorder, 1902, xxiii, p. 195.

‡ Arch. f. Hygiene, 1893, xvii, p. 179.

Bacillus typhosus, Bacillus coli, Bacillus pyocyaneus, and others. His experiments also show the germicidal effect of light upon bacteria in cultures. As to the relative germicidal properties of the rays, he came to this interesting conclusion, in the course of his experiments: "It gradually became evident that the development of typhoid bacilli was not at all prevented by exposure to orange, red, ultra-red, or also (contrary to expectations) ultra-violet light; while the clearest part of the spectrum, green, blue, and to a certain extent violet light, acted in such a way as to prevent the development and to kill the organism."

It will be observed that these investigations as to the effect of light upon bacteria do not offer findings upon which a very strong argument can be made for an essential difference between *x*-rays and light rays. Light rays require the presence of oxygen to destroy bacteria, and the different light rays vary greatly in their actinic properties. Bacteria vary considerably in their resistance to light, and doubtless certain bacteria are wholly unaffected by it. The most significant fact in this connection is the observation of Buchner that the rays of greatest germicidal properties, at least as regards the typhoid bacillus, are those around the blue line of the spectrum, which have a stronger germicidal property than the ultra-violet rays. In other words, according to Buchner's findings, the germicidal properties of light rays do not correspond entirely to their actinic properties. Considering all these facts,—that while light rays are germicidal to certain bacteria they are not to others; that they are not germicidal *per se;* that the different rays of light vary in their germicidal properties; and, what is most significant of all, that the rays of highest germicidal properties are not always the rays of highest actinic properties,—there seems little ground for the assumption that *x*-rays and light rays differ essentially because they do not correspond in their effects on bacteria. The same argument could be used to prove that rays of light in different parts of the spectrum were essentially different forms of energy.

Indeed, the differences between the actinic properties of light and of *x*-rays are so few, and so easily reconciled, that their existence is not to be wondered at, but it is rather a source of wonder that there should not be more.

CHAPTER V.

THE TECHNIQUE OF X-RAY EXPOSURES FOR THERAPEUTIC PURPOSES.

THE central idea in every method of using *x*-rays for therapeutic purposes is to so use the agent as to get a sufficient effect while reducing to a minimum the risk of producing *x*-ray burns of severe character. Different workers go about attaining this end in different ways, and in taking up this subject it may be well to consider first the technique of some of the workers in this field. As a preliminary to this, however, it should be said that it is extremely difficult from any description to arrive at the writer's technique, for the reason that there are so many factors that come into play in determining the intensity and the quality of the rays, the two points of prime importance in every technique. In case a coil is used, the size of the coil, the way it is wound, the amount of the primary current that is used to energize it, are all questions having bearing upon the character of the *x*-rays which are produced. If a static machine, similar questions arise as to its size, its speed, etc. In addition, there come into question the distance of the target from the exposed surface, the length of exposures, the frequency of exposures, and, last and most important of all, and far and away most difficult to determine, the quality of the tube used. These varying factors render the personal judgment of the observer a very important matter in any technique, and that is a thing which cannot be determined from a description. On account of these difficulties, no worker, as far as I know, has yet given an adequate description of his technique. Numerous workers, however, have given descriptions of their techniques sufficiently definite for one to arrive at the general plans which they pursue, and a consideration, as far as possible, of these various plans of procedure is valuable.

Kienböck's Technique.—As a general custom the various

workers assume that there is a variation in the susceptibility of different individuals, and largely on account of this they feel their way along, as it were, until they determine the limits of safety in the treatment of each patient. The most radical exception to this plan of treatment is that advocated by Kienböck.* Kienböck puts down as a postulate that there is no such thing as idiosyncrasy to *x*-rays, and that what is safe for one patient is safe for another. Accordingly he pursues a daring plan of treatment. He advises a coil of 20 to 30 cm. spark length, connected with a lighting circuit, an interrupter giving from 1200 to 2400 interruptions per minute, and regulating *x*-ray tubes. He uses a medium soft tube, which he places at a distance of 15 to 20 cm. from the surface to be treated. The surrounding surface he protects with sheet-lead 0.5 mm. thick, under which he places a flannel strip to protect the skin from sparks. He uses a tube which is capable of producing a good picture of the thorax of a medium-sized man, when viewed through a fluoroscope at a distance of 60 cm. from the focus, and he uses enough light to make a skiagram (he does not say of what, but presumably of the thorax) with an exposure of thirty seconds. If the thorax is meant, that is a very intense light. With this standard amount of *x*-rays he gives exposures of from five to twenty minutes. What he calls a "normal exposure" is an exposure given with such an equipment and under such conditions, and of twenty minutes' duration. "Such an exposure will have the following results: On normal skin, after a period of latency of fourteen days, the hair will fall out, accompanied by an erythema lasting a few days. On skin affected with sycosis the loss of hair will occur as early as the eighth day, accompanied by the formation of numerous pustules. Lupous tissue will become exfoliated after a lapse of a week." He states that the effect of a normal exposure of twenty minutes may be produced by dividing the action of the radiance over several sittings of shorter duration, and he accordingly formulates three methods of *x*-ray therapy. "First: daily sittings with a radiance of slight intensity, continued until the first symptoms of reaction

* Interstate Med. Jour., 1902, ix, pp. 1, 60.

appear. Second: (*a*) sittings with a radiance of medium intensity twice a week until reaction begins to be manifest (about two weeks); or (*b*) three or four sittings with a radiance of medium intensity, given on alternate days. Or, third: the normal exposure in a single sitting and await reaction.

"Treatment by any of these methods is appropriate and conforms to the fundamental principles laid down above. The second is the method to be preferred, inasmuch as the first is tedious for both patient and physician and the third demands a certain experience on the part of the operator. After the first sign of reaction appears we deem it advisable to await the termination of the characteristic inflammatory process, and then if necessary repeat the exposure. If, in using the second and third methods, absolutely no reaction occurs at the end of three weeks, we may feel justified in repeating the normal exposure. If, however, a mild reaction, non-progressive in character, has taken place, an additional exposure less than normal can be applied. As stated above, the second normal exposure is made after the subsidence of the inflammatory reaction excited by the first. Thus this treatment may involve, in accordance with the nature of the case, repetitions of *x*-ray applications extending over months or even years."

It will be observed from his description that Kienböck uses a light of very decided intensity, with which, he states, an experienced operator can give an exposure of twenty minutes at a distance of 15 cm. without any attention to the particular susceptibility of the individual. And he then describes a definite set of reactions which will follow such a "normal exposure." I do not believe any hard and fast description, such as he attempts, of the reaction which will follow a definite exposure can be accepted. Assuming that he can make his light of a definite intensity under all circumstances, which surely cannot be done, all individuals will not react to the same extent. His second and third methods are to my mind dangerous, and they cannot be carried out with safety in all cases. His first method does not differ in any essential particular from the plan of various other workers.

The fundamental fact upon which Kienböck's technique is

based is that there is no variation worthy of consideration in the susceptibility of individuals to *x*-rays. I have previously given my reasons for dissenting entirely from this statement, and Kienböck himself leaves out of consideration in his technique certain variations in susceptibility which he himself thinks he has found in patients—namely, differences in susceptibility of different parts of the body, of healthy and diseased parts, and of young and older individuals. Perhaps in the hands of a very experienced *x*-ray worker such a plan of treatment as Kienböck's may be carried out with reasonable safety, but it requires great experience and unusual judgment, and even under the most favorable circumstances contains, I am sure, elements of grave danger.

Scholtz's Technique.—Scholtz* recommends a plan of treatment somewhat after Kienböck's plan. "After a light preliminary exposure is given (a precaution especially necessary in acne, hypertrichosis, folliculitis barbæ, and eczema), in order to determine the condition of the skin, after a few days a relatively strong exposure is given, so as to produce as soon as possible in the area the desired amount of reaction. Then the intensity of exposure is at once decreased. The later light exposures are continued to the point of getting the desired effect: for example, epilation. This procedure avoids the two extremes, of bringing about an undesired reaction, and of continuing perhaps for weeks insufficient treatment, being similar to that employed in using a drug of slow and cumulative effect. For example, desiring to cause a falling of the hair of the head, in the case of favus, a first exposure is given of fifteen minutes at 30 cm. Then, in three or four days, exposures every other day of fifteen minutes; later every third day, three or four minutes."

For large surfaces he advises a distance of 30 to 40 cm., and for small surfaces a distance of 10 to 15 cm. The tube used should be medium hard, of large volume, and provided with a regulating apparatus. The same objection that I have suggested to Kienböck's method obtains against Scholtz's. A first exposure of fifteen minutes, at a distance of 15 to 40

*Arch. f. Derm. u. Syph., 1902, lix, p. 421.

cm. is dangerous, if a large quantity of *x*-rays is used, which is presumably the case from Scholtz's description.

Oudin's Recommendations.—Oudin * advised: for superficial lesions, a soft tube of about 5 cm. spark equivalent; for deeper lesions an extra hard tube of, say, 8 cm. spark equivalent; the anticathode always placed at 10 cm. from the skin; a current of four amperes and fifteen volts, with 1200 interruptions per minute; first exposure one minute, second one and a half minutes, third two minutes, etc., stopping at first sign of dermatitis; and that when treatment is recommenced, it be given three minutes less than the last. This plan of treatment is particularly advised in order that a common basis on which to judge results may be arrived at.

Williams' Technique.—Williams,† of Boston, whose investigations upon the application of *x*-rays in medicine are among the most valuable that have been made, uses a technique which differs very considerably from any other that has been described. The chief difference in his technique from others is that he uses a tube of very low vacuum, and he varies the quality of light in it by the use of a multiple spark gap, which is inserted in the secondary circuit. By an ingenious device the number of spark gaps may be entirely cut out, or any number of spark gaps up to twenty-five or thirty may be inserted in the circuit. The insertion of this spark gap has the effect of producing *x*-rays in a soft tube that have the quality of the rays produced in harder tubes. The greater the number of spark gaps inserted, the greater the penetrating effect of the rays. This is a device that is of the utmost value, I am sure, in fluoroscopic examinations, but that it adds any essential quality to the *x*-rays for therapeutic purposes seems to me to be in doubt.

His chief reliance in protecting surrounding surfaces from *x*-rays is the enclosure of his tube in a box. This box, which he attributes to Rollins, is made of wood, painted on the inside with several layers of lead paint. In one side there is a circular opening about 5 cm. in diameter, and this diameter can be

* Annales de Derm. et de Syph., 1902, S. iv, t. iii, p. 54.

† The Röntgen Rays in Medicine and Surgery, p. 647.

varied by the use of a diaphragm of heavy sheet-lead. In addition to this lead diaphragm, a diaphragm of plate glass is used in order to prevent sparking from the lead plate. By this method he can project a cone of *x*-rays of any desired size upon a diseased surface. He also at times protects the parts by a mask of gauze covered with tinfoil with windows cut in it to correspond to any area that he desires to treat. He also covers the diaphragm with an aluminum sheet, which is grounded. This box of Williams is ingenious and serves its purpose well. The only objection to it is that it is somewhat cumbersome, and would interfere, I should think, with the application of *x*-rays to comparatively inaccessible parts like the axilla. But when one wishes to have his tube at some distance from the surface, this box is one of the most ingenious devices that has been suggested for shielding surrounding parts from *x*-rays. It is also serviceable in protecting the operator.

Williams uses a considerable quantity of energy in his tube. When I have seen his work, he has run his tube with the center of the target at a cherry-red color. He places the target at a distance of from 10 to 15 cm. from the patient and suggests that, as a rule, the exposures should not exceed ten minutes, and at the beginning be given not oftener than twice a week. My impression is that Williams' technique is highly efficient in his hands, but that it is unnecessarily complicated for therapeutic purposes and requires a high degree of skill upon the part of the operator. For his work Williams uses either a very powerful static machine or a large coil. For therapeutic purposes he prefers a static machine.

Beck's Technique.—Carl Beck,* of New York, does not give a description of his technique, but has the following well-considered remarks to make upon various aspects of the subject:

"In regard to the technique of irradiation for therapeutic purposes, careful individualization is the condition *sine qua non*. . . . . At first it is best to expose for a short time and at long intervals until the individuality of the patient is well studied. Some patients react soon, some after many exposures, and some do not react at all. It should be regarded

* Medical Record, 1902, lxi, p. 83.

as an iron-clad rule to stop the exposures as soon as the patient feels a burning sensation in the irradiated area. Only after symptoms of this kind have again disappeared entirely the irradiations may be repeated. For the first time it is best to expose five minutes only. A week should elapse then before a second exposure is made. If after the third exposure, made two weeks later than the first, no inflammatory signs have shown, the patient does not seem to have an unfavorable idiosyncrasy, longer exposures and shorter intervals can be attempted.

"The exposures may then last ten, twenty, or even forty-five minutes, and may be repeated every other day, in obstinate cases even daily. The risk of burning the patient under such powerful treatment is not small. In the treatment of malignant disease, however, this should not bear great weight. . . . . For the treatment of most skin diseases, however, an exposure of five to ten minutes, repeated every third day, is sufficient.

"The tube is placed as near the area to be irradiated as possible (as an average at a distance of about four inches).

"As a rule, tubes of low vacuum (soft tubes) should be selected for therapeutic purposes."

Schiff and Freund's Technique.—The original suggestions of Schiff and Freund * as to technique were as follows: that a coil be used of 30 cm. spark length, a mechanical interrupter giving from 600 to 1000 interruptions per minute, and a primary current of 12 volts and 1½ amperes; that the length of exposures begin at five minutes and be increased carefully to fifteen minutes; that the tube be placed at the beginning at a distance of 15 cm. from the surface and gradually brought closer to a minimum distance of 5 cm. They advised three preliminary exposures of five minutes each at a distance of 15 cm., and then a wait of three weeks in order to see if any reaction developed. In case any reaction showed itself from three such exposures, it was evidence that the patient had marked susceptibility to *x*-rays.

Factors Affecting the Quality of X-rays.—Schiff and Freund's original technique is, I believe, the most satisfactory attempt

* Wien. med. Wochenschr., 1898, xlviii, pp. 1057, 1118, 1177.

that has yet been made to furnish a definite plan of treatment. It was founded upon a consideration of the various factors which affect the intensity of *x*-rays and their influence upon tissues. As is well known, these factors have chiefly to do with the amperage and voltage of the primary current, the capacity of the coil, the quality of the tube, the rapidity of interruption of the current, the distance of the target from the exposed surface, and the length of exposures. The intensity of the light in the tube, all other factors being equal, varies, according to Röntgen, directly with the strength of the primary current. The character of the secondary current, of course, varies greatly according to the winding of the coil. The rapidity of interruption of the current is a matter of minor but appreciable importance; other factors being the same, the more slowly the current is interrupted the longer are the periods during which the current flows, and the greater is the amount of current which reaches the primary. The effect upon the tissues varies directly with the length of the exposure. *X*-rays diverge in the same way as light rays, so that their effect upon any given surface varies inversely as the square of the distance. The factor of all others among these which is hardest to standardize, and to express accurately, is the resistance and the other qualities of the tube. The quality of the rays and their intensity vary greatly according to the quality of the vacuum in the tube, and this is an unstable factor.

Standard Light.—Following the original suggestions of Schiff and Freund, I used as my standard a light produced in a fairly soft tube by a coil of 12-inch spark length with double winding of the primary, with a primary current of twelve volts and one and one-half amperes, interrupted a thousand times per minute. This current through such a coil produces a thin spark about 3½ inches in length. And this secondary current, through a fairly soft new tube, produces a light that will give clearly the outline of the bones of the hand on a barium platinocyanide screen at a distance not exceeding 20 inches from the tube. I am quite aware that this combination of factors does not by any means give under all circumstances the same amount of *x*-rays, but it never under any circumstances gives more

than a moderate quantity of *x*-rays, even under maximum conditions; and it therefore gives a light which for therapeutic purposes is under almost all circumstances well within the limits of safety. It was, I am sure, of the utmost value to me in getting my experience that I held as closely as possible to this standard combination, because it gave me a fairly reliable unit of measurement in doing this sort of work, and even at the present time, when I depart very widely from these original conditions, I am sure that I still find of service this standard *x*-ray light.

The mode of treatment which I pursue is based upon the repeated use of a small quantity of light, rather than the use of more powerful exposures less frequently. This is, of course, done in the interest of safety.

Influence of Amperage and Voltage.—In my work I have used coils exclusively. The usual coil has been one of 12 inches spark length. The amperage of the primary current is maintained between the extreme limits of one and four amperes. Rarely do I use a current of more than two and one-half amperes. The voltage is not held within such narrow limits. Usually my voltage ranges between twelve and thirty volts, depending upon the resistance of the tube. Rarely—and very rarely—I use a current of 110 volts. Given coils and all other conditions, except the tubes, identical, it does not make a very great deal of difference whether 110 volts or twenty or thirty volts are used. It is unquestionably true that safety to the patient with a current of high voltage requires considerably more care than with twenty or thirty volts. The lower voltage is also safer for the apparatus. The amperage is of more importance. The secondary current which gives a thick fat spark and which is produced by a primary current of high amperage is the current which gives a large quantity of *x*-rays, and which is therefore most liable to cause damage.

Quality of Tubes.—With this rather weak secondary current I use tubes of varying degrees of hardness. The aim is to so correlate the quality of the tubes and the strength of the secondary current as to produce under all circumstances as nearly as possible the same quantity of *x*-rays. The determination

of this quantity of *x*-rays is, of course, largely a matter of judgment and personal experience, but a little practice in the use of one's apparatus under definite conditions enables one to judge with reasonable accuracy of the intensity of one's light.

Duration and Distance.—With such a light, I begin with exposures at 15 cm. from the surface to the wall of the tube, and gradually reduce the distance so that by the end of two weeks, if there is no evidence of reaction, the tube is placed at a distance of from 5 to 8 cm. from the exposed surface.* At the end of two weeks I begin to increase the length of exposure, and by the end of two weeks more I increase the time, if no reaction appears, up to fifteen minutes. The maximum exposure which I give, except the rarest cases, is fifteen minutes at 5 cm. from the wall of the tube.

Frequency of Exposure.—With such a light as I use, exposures can usually be given daily for two or three weeks without the production of any marked degree of dermatitis. The frequency of exposures is varied according to circumstances. When it can be done and when it is desired to get the tissues promptly under the influence of *x*-rays, my plan is to give exposures six days in the week. With experience the same effect may be obtained by three or even two exposures a week, but it requires a good deal more skill in crowding the exposures.

Preliminary Exposures to Determine Susceptibility.—When, as in cases of acne and hypertrichosis, I wish to exercise extreme caution, I give three preliminary exposures of five minutes each with the tube at 15 cm. distance with a weak standard light on three successive days, and then wait three weeks to see if any reaction occurs. This is after the suggestion of Schiff and Freund to determine idiosyncrasy. Such preliminary exposures are, I believe, an excess of caution under most circumstances.

Distance of Tube.—The distance at which I place my tube is, as I have said, from 15 to 5 cm. from the surface. When

*Of course, it is more accurate to measure the distance from the target to the surface, but as a matter of convenience I have always measured from the tube, and, except when the tube is very near, it does not cause material error.

it is desired to produce a decided effect, the tube is usually maintained at 5 to 8 cm. There is an objection to the use of the tube very close in case it is desired to influence a large surface, for the reason that under such circumstances the effect is relatively so much greater at the point directly beneath the target. For this reason if a large surface is to be influenced,—as, for example, the entire back in treating an acne,—it is necessary to place the tube at a greater distance, say 15 to 30 cm.

If exposures are to be given daily with the tube at a distance of 5 cm. and ten to fifteen minutes' duration, one must be careful to keep a weak light. With a light such as I have attempted to describe, the exposure can be continued daily, as I have done in many cases, without ever producing a serious burn. I have made many thousand exposures of the above character, in many instances have produced acute dermatitis intentionally, but I have never in any case had a burn that caused destruction of the connective tissue. I feel able to push these treatments, therefore, with considerable assurance—a point of importance when a prompt effect is desired.

Record of Exposures.—It has been my practice from the start to keep as accurate a record as possible of all the factors of the exposure. A copy of the record sheet which I have used is shown in miniature in figure 97. The following data are recorded for each exposure: the number and date of the exposure, the voltage and amperage of the primary current, the distance of the tube from the surface, the length of exposure, the number of interruptions per minute, the area exposed, the quality of the tube, and the intensity of the light. For convenience I have classified the tubes into hard, medium, and soft, and the quality of light as weak, medium, strong, and very strong. With a little attention to system, the recording of all these data gives very little trouble, and the possession of such data in many cases I have found of the utmost value in formulating methods of procedure in any given case.

Necessary Apparatus.—To carry out the technique that I use the apparatus required consists of a coil, motor generator or storage battery, switchboard with volt meter and ammeter

and necessary switches and rheostats, mechanical interrupter, tube-holder, tubes, and lead masks. The various parts of this apparatus will be taken up in considering apparatus in general. An apparatus such as I use is shown in figure 98.

It will be evident from the foregoing description of the techniques of different workers that any technique is largely a matter of personal experience. Different workers arrive at the same end by very different methods. It is for this reason that I have thought it worth while to describe in some detail the

Name.....

No.	Date.	Volts.	Amp.	Dist.	Time.	Inter.	Area.

Fig. 97.

methods of several of the best-known workers in this field, and for the same reason I have ventured to impose on the reader's patience a somewhat detailed description of my own.

Whatever plan of treatment the worker adopts it is well in my opinion to stick to one technique as closely as possible, in order that he may accumulate an experience under as definite conditions as possible. It is only by such a systematic technique that he can profit by his past experience.

How Far Should X-ray Effects be Carried?—In many conditions, as acne, eczema, and other inflammatory conditions of the skin, it is possible to get rid of the disease without at any time producing apparent *x*-ray effects upon the skin, and in such cases it is not necessary to carry the treatment to the point of producing any reaction in the tissues. In other conditions it may be necessary to push the *x*-rays much further, and under such circumstances the question constantly arises, How far shall the *x*-ray effects be pushed? The rule is frequently laid down that exposures should be stopped immediately upon the first appearance of reaction in the skin. That is a rule that I usually follow in the first treatment of any case, and never transgress in the treatment of minor troubles like acne.

As a rule, upon the first appearance of any effect upon the skin the treatment is stopped,—unless the situation is grave,—and I then wait for the reaction to subside. When this subsides, the treatment is again begun.

If the patient has shown no marked susceptibility to the effect of *x*-rays, and there is reason for pushing the treatment, the second time I do not hesitate to continue the treatment in spite of moderate dermatitis. Under certain conditions I push the treatment up to the development of an acute weeping dermatitis, and in very rare instances I have continued treatment for a considerable time over such a dermatitis. Of course, that should not be done unless the situation is sufficiently grave to warrant the risk, and then should be done with as much caution as possible. It is by no means always necessary to carry the exposure to the point of producing dermatitis in the healthy skin in order to destroy pathological tissues. For example, in Case 76, page 472, of extensive recurrent carcinoma of the chest-wall, all of the carcinomatous tissue disappeared, and was replaced by healthy scar tissue without even an erythema ever being produced. There was slight pigmentation, but nothing more. On the other hand, in a similar case, Case 75, page 471, it was found necessary to carry the reaction to the point of producing an acute weeping dermatitis repeatedly before the carcinomatous nodules disappeared.

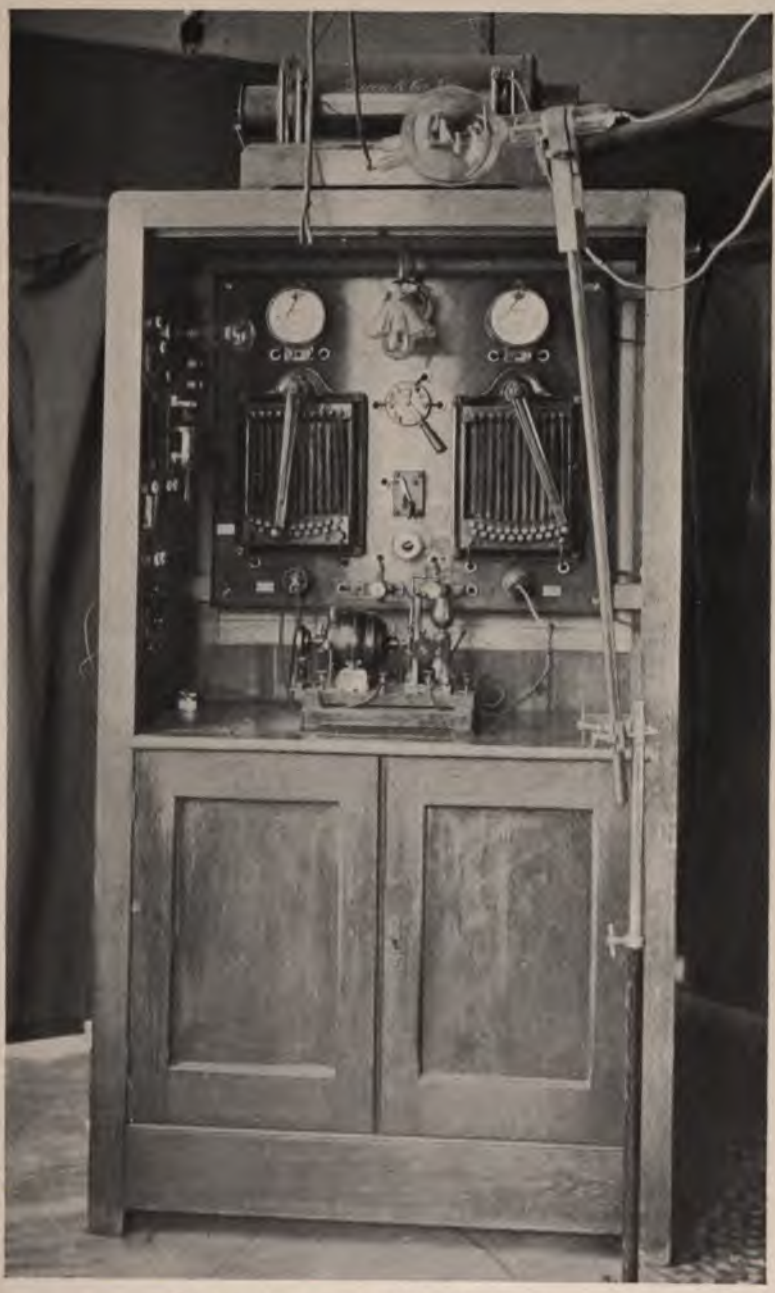


Fig. 98.—An x-ray outfit for therapeutic use.

Tissues vary a great deal in these respects, and each case has to be treated according to its individual peculiarities. I wish to emphasize, however, the fact that in carcinoma and other malignant diseases it is by no means always necessary to produce an *x*-ray burn, even of the first degree, in order to get rid of the diseased tissue. Johnson and Merrill,* in considering this point, suggest that it is necessary to produce an *x*-ray burn, according to the reports in the literature, in order to get rid of an epithelioma, and therefore they see no reason why the operator should not proceed to do this as quickly as possible. I am sure from my experience that it is not always necessary to produce an *x*-ray burn in order to get rid of malignant growths.

In a general way, of course, much more care must be exercised to avoid burns in conditions that are not grave than in serious malignant diseases. The greatest care is to be exercised in treating simple skin diseases, which at their worst are perhaps less serious than an *x*-ray burn. In the treatment of malignant diseases much less care may be exercised as regards the factors of safety, and under some circumstances they may be disregarded, and all energies bent to the production of *x*-ray effect upon the tissues as quickly as possible, regardless of the risk of burn.

There are certain questions pertaining to technique which have only been considered incidentally in the foregoing and which need a more general consideration.

Apparatus.—Most of those who have used *x*-rays for therapeutic purposes have used induction coils as their source of energy. Some have used static machines, and a very few have used the so-called Tesla high frequency apparatus.

Coils vs. Static Machines.—I prefer coils to static machines, for the reason that the amount of energy to be used can, in my opinion, be gauged more accurately with the coil, and can also be more accurately regulated. Williams, on the other hand, prefers the static machine. It is doubtless a good deal a matter of personal experience. There is no reason to believe that the *x*-rays themselves produced by a static machine differ

* Phila. Med. Jour., 1900, vi, p. 1138.

in any way from those produced by a coil. It is only a question, therefore, of convenience and accuracy in the management of the agent. In the hands of an expert worker the static machine may doubtless be used as a source of *x*-rays with as much safety as the most carefully regulated coil. A static machine does, however, require more skill to keep it well within the bounds of safety. There is, in my opinion, not the slightest vestige of reason for the claim that *x*-rays produced by a static machine are less liable to cause burns than those produced by coils. Upon this point Codman * makes the following very conservative statement: "Many assertions have been made that the static machine is less liable to cause injury than other forms of apparatus because of the lower amperage of its output. This statement is not entirely borne out by the present analysis. In the cases in which the kind of apparatus is recorded eleven were caused by static machines; of these, three were severe. Eleven were caused by Tesla coils; of these, five were severe. Forty-two were caused by forms of induction coil; of these, eighteen were severe. On the other hand, coils have been far more commonly used than static machines or the Tesla apparatus —probably more than three times as much." As bad burns as there are recorded in the literature have been produced with static machines, as witness the case reported by Cassidy.† This is, of course, no argument against the use of static machines for therapeutic purposes, for unquestionably *x*-rays which would not produce burns (if such existed) would be of no service in the therapeutic use of the agent. The quality in *x*-rays that produces burns is the same quality that is utilized in the therapeutic application of the agent. The Tesla high frequency apparatus is, in my opinion, less to be recommended for the production of *x*-rays for therapeutic purposes than either of the other two forms. It produces a large quantity of *x*-rays, and its use therefore requires more care than either of the others. It has been used, however, in the successful application of *x*-rays to therapeutic purposes. It has a minor objection, in that it very rapidly blackens the tubes and causes their deterioration.

Coils.—For most of my work I have used coils of 12-inch

* Phila. Med. Jour., 1902, ix, p. 438. † Medical Record, 1900, lvii, p. 180.

spark length with double windings of the primary, so arranged that they can be connected either parallel or in series. A number of writers have recommended much larger coils, but without reasons that to my mind are conclusive. A coil that will produce a good spark of 12 inches can furnish more energy than we can utilize or than would be safe for therapeutic purposes if we had a tube that would take it. In my work I rarely use a current of sufficient strength to produce a 12-inch spark, so that even smaller coils may be used. Indeed as a portable apparatus I have constantly used with satisfaction coils of 6 or 7 inches spark length with vibrator interrupter and storage batteries.

Sources of Energy.—On account of the convenience of its use the 110-volt direct current taken directly from lighting circuits is often recommended, particularly by the manufacturers of electrical instruments. It can unquestionably be used, but it cannot be used, I am convinced, with as much safety as a current of lower potential. For that reason, although I have always had the 110-volt continuous current at my disposal, I have for most of my work converted it, either by the use of a storage battery or a motor generator, to a current of lower voltage. It is easy to have the wiring of one's switchboard so arranged that the 110-volt current can be made available, and at times it is desirable to use it; but for the sake of uniformity in technique, if not for safety, I very rarely avail myself of it. For converting the 110-volt current to a lower voltage either a storage battery or a motor generator is satisfactory. My storage batteries are arranged so that any voltage from 12 to 25 volts can be obtained, and so that they can be stored by simply throwing a switch. I have found storage batteries so arranged entirely satisfactory for my work. More frequently than a storage battery I use a motor generator so wound that any voltage between 10 and 40 volts can be obtained. A one-fourth horse-power generator will furnish ample energy. For continuous use a motor generator is perhaps more satisfactory than a storage battery.

Meters.—For the sake of accuracy I have constantly used meters on my primary current: a volt meter registering from 1 to 120 volts and an ammeter registering from $\frac{1}{4}$ to 10 amperes.

In my opinion they are highly desirable, though not absolutely necessary, additions to the apparatus, since they furnish a factor of stability and safety in the technique. A tachometer to register the number of interruptions in the current is a desirable but not necessary part of the apparatus.

Interrupters.—For small coils the ordinary vibrator interrupter gives satisfactory results, but for coils above 7 or 8 inches spark length it is usually not satisfactory. There are, however, being put on the market at present some coils of 12 and 15 inches spark length, equipped with vibrator interrupters, that give good results. There are various forms of mechanical interrupters in use. The dip interrupter, in which the current is made by the rapid dipping of a platinum tip in mercury under kerosene or alcohol, and the turbine interrupter, in which the current is made by a rapidly revolving jet of mercury impinging upon the segments of a metal collar, are the two principal types. Either answers the purpose satisfactorily. In its present perfection the turbine interrupter is perhaps the best type. The dip interrupter, however, has one very material advantage over the turbine interrupter for therapeutic purposes, and that is the amount of amperage of the circuit can be conveniently regulated without changing the voltage by varying the depth to which the needle of the interrupter dips into the mercury. The electrolytic or Wehnelt interrupter is not quite so satisfactory for therapeutic purposes, because it requires a high initial voltage, and in a coil that is ordinarily wound it produces a heavy spark. To get such a spark as I use with a Wehnelt interrupter requires a special winding of the primary in three or four layers, and this winding is not suitable for any other interrupter.*

Tube-holders.—A tube-holder made of iron tubing which I have found very convenient is shown in figure 99. A similar tube-holder, which has the advantage of being made of wood, is shown in figure 100. I have found these holders convenient for therapeutic work because the arm holding the tube is long and the tube can be readily adjusted in any position.

* Walter: Fortschr. a. d. Geb. d. Röntgenstrahlen, 1900, iv, p. 46; 1901, v, 13.

Tubes.—As is well known, tubes are described as hard or high, or soft or low, after the suggestion of Röntgen, according to the character of the vacuum and the resistance which they offer to the electrical current. A tube is spoken of as soft when it is of low vacuum and of correspondingly low resistance; as hard when the vacuum is relatively high and the resistance correspondingly increased. The quality and quantity of the *x*-rays vary according to the degree of vacuum of the tube.

Fig. 99.

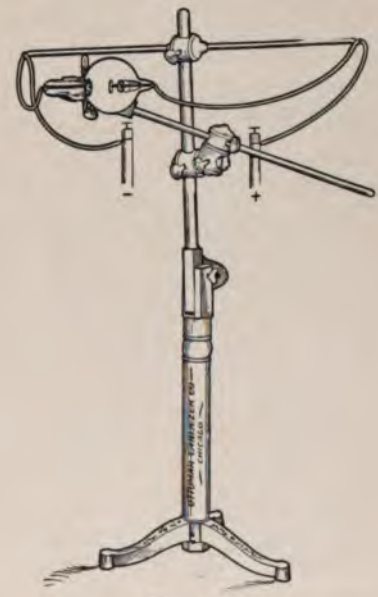


Fig. 100.

The rays from a soft tube are of relatively low penetration, and this penetrating power increases directly with the degree of hardness of the tube. The quantity of *x*-rays also varies with the hardness of the tube. A soft tube will, under given conditions of current, produce a larger quantity of *x*-rays than a hard tube. The quality and quantity of the rays also vary considerably with the age of the tube. A new tube under given conditions of current will produce a larger quantity of

x-rays than can be produced in the same tube under the same conditions after it has been used for a long time, regardless of its vacuum. A tube, moreover, tends to become harder from use, so that for this reason, also, to produce a given quantity of light a larger quantity of energy will be required in the old tube than in the new one. It is a fact of practical interest that old tubes may be improved by giving them rest from use. I am using now the first tube I ever used; it became so high that no *x*-rays could be gotten from it, but after a rest of several months it was restored to moderate hardness.

No satisfactory standard for classifying or describing tubes has yet been found. The usual plan of expressing the hardness of tubes is by describing them in equivalent spark length. A given tube has an equivalent resistance of so many centimeters spark length; that is, the resistance which the tube offers to the passage of the current is the same as that offered by a certain spark gap in the air, so that if this spark gap is made less the current will pass across the gap rather than through the tube, or if greater will pass through the tube rather than across the gap. This, however, expresses only the resistance of the tube and furnishes no accurate statement of the light produced by such a tube.

The usual and perhaps the most practical way of describing the light from any tube is by using the shadow cast by the hand as a standard. The difference in the shadows of the hand produced by *x*-rays of different degrees of penetration is very well shown diagramatically in the accompanying illustrations taken from Kienböck * (Fig. 101).

In the treatment of pathological conditions tubes must be selected with a view to the depth of tissue which it is desired to affect. It is generally accepted that soft tubes produce a greater effect upon the superficial tissues than hard tubes (Scholtz,† Taylor,‡ Kienböck,§ and Sharpe‖). This is undoubtedly for the reason that only those rays which are absorbed

* Wien. klin. Woch., 1900, xiii, p. 1153.

† Arch. f. Derm. u. Syph., 1902, lix, p. 241.

‡ Lancet, 1902, i, p. 1395.

§ Wien. klin. Woch., 1900, xiii, pp. 1153, 1166.

‖ Archives of the Röntgen Rays, 1901, v, p. 83.

by the tissues produce any effect upon them, and the rays from a soft tube are absorbed by the most superficial tissues, while those from hard tubes pass through the superficial tissues

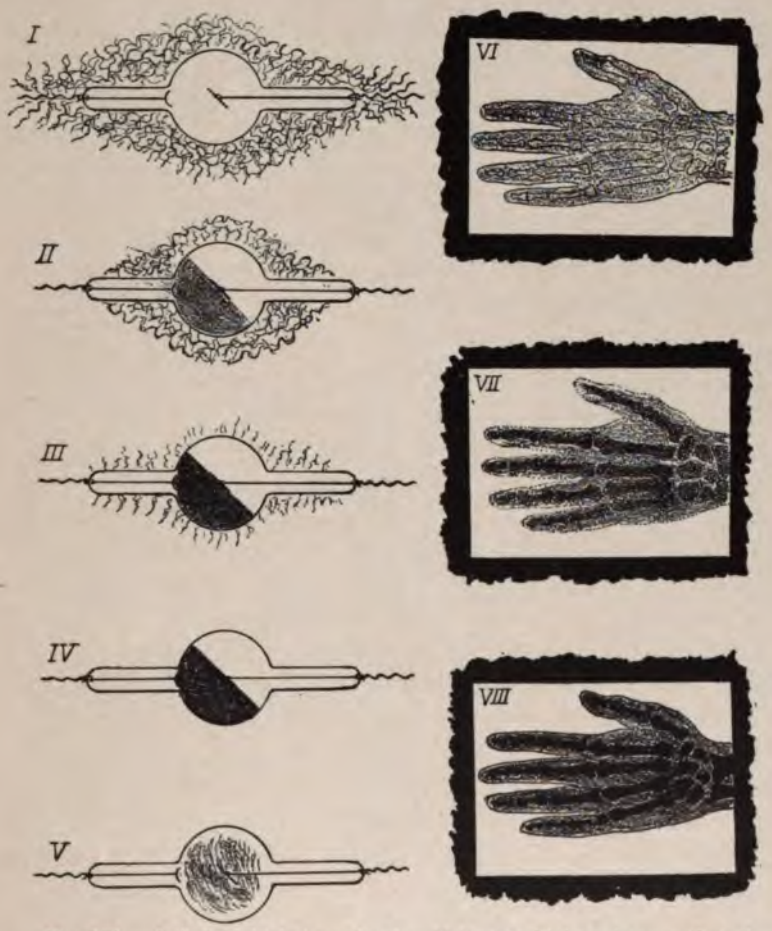


Fig. 101.—*I*, Tube which is so hard and of such high resistance that the current cannot be forced through it, but passes around it through the air. Gives no Röntgen rays. *II*, Hard tube of high resistance giving Röntgen rays of high penetrating quality. The soft parts and the bones are about equally well penetrated by the rays, and very little light is absorbed. The shadow of the hand given by such a tube is shown in *VI*. *III*, Medium soft tube. Almost the entire electrical current passes through the tube and is transformed into Röntgen rays. Gives an intense radiance of moderate penetration. Shadow of the hand from such a tube is shown in *VII*. *IV*, Very soft tube. Gives intense *x*-rays with a current of low power. Its light has only a slight penetrating power. In the shadow picture (*VIII*) both the soft tissues and the bones are dark. *V*, Tube which is so soft that no *x*-rays are produced.

with a minimum absorption. There is accordingly a well-defined consensus of opinion that in the treatment of superficial conditions like skin diseases soft tubes are the most suitable, while for deep-seated conditions hard tubes of greater penetration must be used. I have no doubt of the accuracy of this position. Deep-seated conditions, if they are to be affected at all, can be affected only by relatively hard tubes; while superficial conditions are most readily affected by soft tubes. From all, however, but the tubes of highest vacuum x-rays can be produced which will show a perceptible effect on the most superficial tissues; for no matter how high a tube may be, some of the rays are absorbed by the first tissues they strike. For the treatment of deep-seated processes I have at

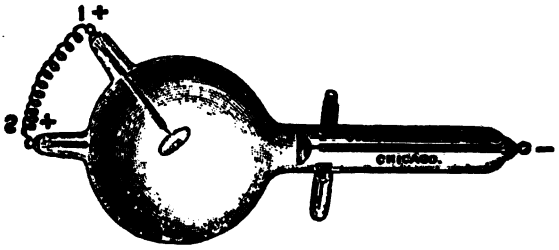


Fig. 102.—Tube with regenerating attachment.

times used with apparent success very old and very hard tubes whose rays were of such penetrating power that they produced almost no effect upon a fluorescent screen. Very few of the rays from such a tube are absorbed by the skin, so that the treatment of deep-seated affections can be carried out much more vigorously with such tubes than would otherwise be possible.

As to the variety of tubes which should be used, I have not found any one make that shows distinct superiority over all others. The style of tube which I usually use is the ordinary spherical tube (Fig. 102). These tubes are furnished either without regulating device or with a capillary tube of palladium alloy, as suggested by Villard,* protruding through the tube

* Londe: Annales de la Conservatoire des Arts et des Metiers, 1899, 3e Série, i, p. 153.

wall, by heating which the vacuum in the tube can be lowered. The tubes with this regulating device are worth the small difference in price between them and the non-regulating tubes. The tubes with the so-called self-regulating device I have not found to possess marked superiority for therapeutic work. They have a little longer life, but the difference in this respect has not been sufficient to compensate for their greater cost. If one has a single *x*-ray tube, it is perhaps better to have one of these self-regulating tubes, but it has seemed to me a better plan to have several tubes of different ages and different vacua, from which one may select a tube to suit any particular case. Another advantage in having several tubes is that the tubes may be rested for a while, for those that are put out of use for several days or weeks often regain some of their lost quality. I prefer tubes of medium size, with a bulb about six inches in diameter. Such a tube is large enough to have a relatively stable vacuum and not so large as to be inconvenient for use. At times smaller tubes with a diameter of bulb of 4½ inches are convenient for treating the perineum, axilla, and other comparatively inaccessible parts. For use in cavities—as the vagina, rectum, mouth—Caldwell's tube is of the utmost value.

Protectives.—In all methods of using *x*-rays for therapeutic purposes provisions are made for protecting the surfaces surrounding the part to be treated. There are two ways of doing this: one is to surround the tube with an opaque covering so that the rays have exit only at one point; the other is to protect by some opaque covering the surfaces of the body which are within the influence of the rays. The first method is usually carried out by placing the tube in a box. An example of these boxes is Williams' box (Fig. 103), to which reference has already been made. The advantages of and objections to this plan have been briefly referred to in considering Williams' technique on page 306. The second method consists in using shields to cover the surface adjacent to the tube, with openings cut in them to correspond to the area which it is desired to expose. The first material suggested for these shields was lead, and lead in some form is the material still generally used.

Schiff and Freund * suggested sheet-lead, $\frac{1}{50}$ of an inch thick, to be covered with blotting-paper. Kienböck † uses lead plates which he covers with flannel. Williams uses for the face "a mask made of gauze and pressed into the shape of the face, such as may be purchased at theatrical supply houses," and he covers this with tinfoil. Others have suggested the use of several layers of lead-foil such as is used for lining tea boxes. I use in my work sheet-lead $\frac{1}{50}$ or $\frac{1}{32}$ of an inch thick. Recently I have used sheets made from an alloy of 95 per cent. lead and 5 per cent. tin. This has the advantage of being bright and clean and not rubbing off in handling. Röntgen states that sheet-lead $\frac{1}{16}$ of an inch thick practically excludes

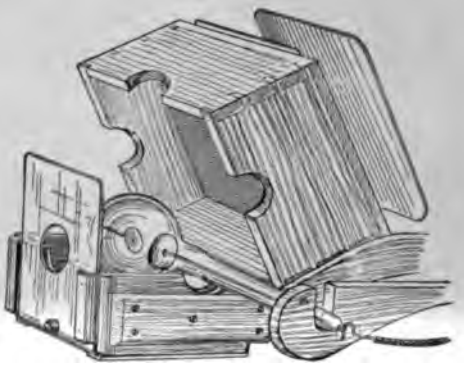


Fig. 103.—Williams' tube-box.

all *x*-rays. I have found on trial that a rapid photographic plate covered with lead $\frac{1}{25}$ of an inch thick shows almost no trace of *x*-rays after fifteen minutes' exposure to a strongly lighted hard tube. Fifteen minutes' exposure to a similar light of a photographic plate covered by $\frac{1}{50}$ inch lead shows appreciable but very slight effect. The $\frac{1}{50}$ inch lead therefore probably furnishes perfect protection. However, I have found that lead $\frac{1}{32}$ of an inch thick is not too thick to be conveniently handled, and it is, I believe, best for these masks. Lead of this thickness can be obtained in any width from any plumbers'

* Wien. med. Woch., 1898, xlviii, pp. 1057, 1118, 1177.
† Interstate Med. Jour., 1902, ix, pp. 1, 60.

supply house. My practice from the start has been to cover the masks on both sides with ordinary wrapping-paper. This makes them clean to handle, furnishes satisfactory insulation, and has the convenience of being easily washed off and replaced. It is simpler than the other coverings suggested and can be more readily renewed. These lead sheets can be made of any size, with apertures in them of any desired shape, and very little ingenuity is required to adapt them to any of the surfaces of the body. For most work about the face these masks can be very readily adapted without especial shaping, but when it is desired to make a mask of the shape of the face I have found it exceedingly convenient to possess a model of the head and neck made in wood. On this mould it is easy after a little practice to hammer these lead sheets into perfect masks of the face. Holes of any shape can be cut in them and the masks then covered with paper. For exposing special parts masks of special design are required, but with a little patience I have never found it difficult to adapt a mask to any part of the body.

Masks for Special Parts of the Body.—In making exposures in the mouth and pharynx I have used a lead mask of sufficient size to cover the face; to this is soldered at right angles a short piece of block-tin pipe such as plumbers use, and a hole is cut through the mask to correspond with the hole in the pipe. This pipe can be moulded or cut to the shape desired. In this way a speculum can be improvised which I have found quite useful. The patients have not objected to it. For making vaginal exposures I have used the ordinary Ferguson short glass specula. The patient is placed on an ordinary gynecological table on the back with the knees drawn up as for vaginal examination. The thighs are protected by lead masks which reach from below the knees to the inguinal folds; another mask is made wide enough entirely to protect the perineum, with a slit in it corresponding in width to the speculum. This is placed around the speculum in such a way as to protect the perineum. The speculum must be retained in position by an assistant's hand, and the additional protection needed in order to cover all exposed parts is furnished by a lead mask which

the assistant places around her hand. This plan of protecting the perineum, while apparently cumbersome, has proved satisfactory and not difficult to carry out.

For making exposures in the mouth or in the vagina or in the rectum Caldwell's tubes (Figs. 21–24) furnish far and away the best method. Indeed, his tubes for treating these cavities is, in my opinion, the greatest single addition that has been made to the technique of the therapeutic application of *x*-rays.

The most difficult skin surface to reach is that around the eyes. Lesions at the canthi can easily be treated because of their distance from the cornea, but in treating lesions of the lower lid and of the upper lid it is more difficult to protect the eyes. It is difficult to protect the conjunctiva in exposing the upper lids. In such cases one has to rely largely upon giving the exposures very cautiously. Fortunately the commonest lesions which we are called upon to treat about the eye, epitheliomata, rarely occur primarily on the upper lid. Lesions on the lower lid I have been able to treat very easily by shaping the masks to correspond with the curve of the eyeball and carefully cutting slits to correspond to the area on the lower lid to be exposed. Then, when making the exposure, I have the lower lid pulled down in order to get it as far away from the bulb as possible. This can be done conveniently by taking a strip of adhesive plaster and fastening it below the border of the lid where the tissues are lax, and having the patient exercise continuous slight traction downward during the exposure. By a little care and ingenuity it is not difficult to treat lesions about the eye. Sometimes, however, in spite of the utmost caution some conjunctivitis will be caused, and if the conjunctiva or the cornea has to be exposed conjunctivitis may be severe. All of the conjunctivitides that I have seen under the influence of *x*-ray exposures have yielded to instillation of protargol solution and boric acid solution, after the manner of treating ordinary conjunctivitis.

A good deal of ingenuity has been wasted in trying to devise masks to supersede lead or other metals opaque to *x*-rays. Among others hard-rubber, papier-maché, and celluloid masks

have been suggested. None of these is opaque to *x*-rays, and none furnishes adequate protection against the effect of *x*-rays on tissues. If for any reason it is impossible to use lead, some slight protection may be obtained from the use of the oxid of zinc adhesive plaster. It is also possible to make a paste of an indifferent ointment and some powder opaque to *x*-rays that will give protection. If bismuth subnitrate, which is opaque to *x*-rays, is rubbed in sufficient quantities with vaselin, or any other indifferent ointment, a paste may be made which furnishes strong obstruction to *x*-rays. A layer $\frac{1}{4}$ of an inch thick of a paste made of two parts by weight of bismuth subnitrate and one of diachylon ointment casts a shadow as dense as that cast by a lead plate $\frac{1}{32}$ of an inch thick.

At one time it was said that coating with vaselin a surface to be exposed to *x*-rays would protect it against *x*-ray burns. I have seen *x*-ray burns occur in many instances under vaselin and other ointments. Lately the interposition of a layer of paraffin has been suggested for the same purpose. This suggestion is doubtless a lineal descendant of the vaselin idea, and is absolutely useless. I have experimentally produced *x*-ray burns under a coating of paraffin $\frac{1}{16}$ of an inch thick,* and I have no doubt that with equal ease I can produce a burn under a layer of paraffin of $\frac{1}{2}$ inch or an inch in thickness. Indeed, I think it may be stated dogmatically that nothing will prevent *x*-ray effects upon the tissues except substances which are opaque to the rays. The only thing necessary to produce *x*-ray effects upon the tissues is for the rays themselves to reach the exposed surface.

Aluminum Screens.—The only suggestion for reducing the likelihood of burns in surfaces exposed to *x*-rays that is of any value is the one made by Elihu Thomson,† that an aluminum screen be interposed between the *x*-rays and the exposed surface. Thomson suggested the aluminum screen on the ground that, while entirely transparent to the more penetrating rays, it would absorb the softest rays, those which have

* Jour. Am. Med. Assoc., 1902, xxxix, p. 923.

† Boston Med. and Surg. Jour., 1896, cxxxv, p. 610.

the greatest effect upon the skin. The use of such an aluminum screen of the thickness of $\frac{1}{50}$ or $\frac{1}{100}$ of an inch has a marked effect in preventing dermatitis, and is advisable, in my opinion, in making all exposures for therapeutic purposes except where the aim is to produce the effect solely or chiefly on the skin. There is no difficulty in producing an *x*-ray burn through an aluminum screen. I have produced dermatitis under such a screen in many cases. It was recommended by Tesla * that this screen be grounded in order to prevent burns. As I have shown by experiment on page 290, there is no difficulty in producing a burn through such a screen even when grounded, and I believe the grounding of the screen to be useless.

Insulation of Patient.—Kümmell,† working in the opposite direction, has stated that the influence of exposures is increased by having the patient sit upon an insulated stool. There is to my mind no reason to believe that such insulation has the slightest effect.

* Electrical Review, Dec. 2, 1896.
† Arch. f. klin. Chir., 1898, lvii, p. 630.

CHAPTER VI.

TREATMENT OF X-RAY BURNS.

In connection with the consideration of *x*-ray exposures for therapeutic purposes, we may well consider the subject of *x*-ray burns, since it is often necessary to carry the reaction to the point of producing some degree of burn in order to get the desired result, and since it may at times be impossible when giving *x*-ray exposures for therapeutic purposes to avoid, even if one would, *x*-ray burns of more or less severity.

The treatment of *x*-ray burns is along ordinary medical and surgical lines. The burns without destruction of connective tissue are treated by the soothing applications generally used for other forms of dermatitis, and the deep-seated burns are handled in the same way as other sluggish painful ulcers that show little tendency to heal. In a general way one has to proceed tentatively in the treatment of *x*-ray burns, until he finds an application that gives relief. In burns of the first and second degree simple dusting powders have been found to give most relief in some cases; in others, soothing, mildly astringent lotions; in others, salves of similar properties As a salve base for *x*-ray burns lanolin was suggested first by Schiff and Freund,* and it seems to be the favorite. According to Butler and Leonard, a diachylon ointment made with lead plaster six drachms and cosmolin two drachms is a very soothing base. In my experience plain vaselin, rose ointment, or equal parts of lanolin and rose ointment have all proved of use. Leonard † recommends for the slight degrees of burn weak solutions of liquor plumbi subacetatis. In the severer forms he recommends an ointment containing fifteen grains of antipyrin to the ounce to relieve pain. In the case reported by Cassidy stearate of zinc powder was a comfortable application for the dry dermatitis. On the

* Wien. med. Wochenschr., 1898, pp. 1057, 1118, 1177.

† American X-ray Journal, 1898, iii, p. 453.

ulcerating surface ointments afforded relief, but any poultice or wet dressing of whatever nature would in half an hour or less produce the most agonizing pain. During the continuance of the slough, which in this case was accompanied by severe pain, the only relief was from large doses of morphin. Butler,* who had a considerable experience in treating *x*-ray burns, found that in dermatitis without severe ulceration ichthyol and lanolin, equal parts, gave relief. In another case relief was obtained from hot, wet dressings of carbolic acid 1 : 100. To cause softening of the slough he used with satisfaction an ointment of lead plaster, six drachms; cosmolin, two drachms; salicylic acid, ten grains. His conclusions as to treatment are as follows: "Proper treatment hastens recovery considerably, contrary to the statement of Moullin and others. Burns of first degree are benefited by the continued application of ointments, especially having a lanolin base. Various ointments and drying powders increase the amount and thickness of necrotic membrane in burns of the third degree. Hot, moist, mildly antiseptic dressings used early in burns of second and third degree help to limit extent of ulceration, and used late help to hasten the process of repair."

Codman's † summary of treatment of severe burns is as follows: "Two main lines of treatment may be mentioned (*a*) physiological rest and mild poulticing; and (*b*) excision, followed by skin grafting. The first should be used at least until the process has become stationary and has ceased spreading; the second, only when the pain is severe and rest has not produced improvement."

It will be seen from the foregoing suggestions of various writers that the treatment presents nothing novel. I have had considerable experience in treating *x*-ray dermatitis that stopped short of ulceration and I have seen nothing to indicate that these cases should not be treated in the same way as similar degrees of dermatitis due to other causes. The one difficulty in the treatment is the uncertainty as to the suitability of any application in a given case. An application that will be

* American Practitioner and News, 1900, xxix, p. 361.

† Phila. Med. Jour., 1902, ix, p. 438.

comfortable in one case will irritate the next similar case, so that it becomes necessary in the treatment of any case to proceed tentatively until a comfortable application is found. The best indication that an application is satisfactory is the fact that it gives relief, and *per contra* I should not persist in the use of any application that was not soothing. In dry dermatitis the use of a light inert dusting powder, like stearate of zinc or talcum and boric acid, often relieves itching and is sufficient. In other cases more comfort is obtained from a lotion. The well-known calamin and zinc oxid lotion, of the following formula, I have found very useful:

Calamin Zinc oxid	of each, one ounce,
Water	one pint,
Glycerin Carbolic acid	of each, 1 to 2 drachms.

In some of these cases lead and opium wash has proved most comfortable, usually used in the proportion of—

Tincture of opium	1 ounce,
Subacetate of lead	1 ounce,
Water	q. s. a. 1 pint.

Again, I have found exceedingly soothing in some cases applications of the so-called "liquor Burrowii," a solution of aluminum acetate 1 to 5 per cent. in water. I have found that other similar cases get the most comfort from an ointment such as lanolin and rose ointment equal parts with a drachm of boric acid to the ounce. Lanolin alone has not proved as satisfactory with me as the lanolin mixture described above.

In cases of weeping dermatitis I have used compresses of lead and opium most frequently, and I have found this plan of treatment very satisfactory. In other cases boric acid compresses have been satisfactory or compresses of aluminum acetate, or ointments such as those mentioned above. I have found vaselin and boric acid a good application in many cases, but in some, in which it was irritating, a rose ointment or lanolin and rose ointment base proved soothing.

In the lesions accompanied by slough the relief of pain is

the first indication. Butler * has used orthoform to meet this indication, and I have used it satisfactorily in combination with compresses of lead and opium. But orthoform should be used very cautiously about *x*-ray burns, for about one patient in ten will get up a dermatitis under orthoform that might cause considerable confusion in connection with an *x*-ray burn. Leonard † recommends to relieve the pain an ointment containing 3 per cent. antipyrin. The separation of the slough in these cases should be promoted as much as possible, and be followed by the use of stimulating applications, very cautiously applied at first. In certain of the cases in which the pain is very severe and almost no tendency to recovery exists, the best plan of treatment is excision of the affected area and subsequent skin grafting. This has been done successfully in many cases.

Care to Avoid Burns in X-ray Workers.—Attention has been called, while considering *x*-ray burns, to the chronic *x*-ray effects that are frequently seen in *x*-ray workers. There are a surprisingly large number of *x*-ray workers who have suffered from acute *x*-ray effects, or who are sufferers from chronic *x*-ray effects. Of course, there is no way for persons who constantly work around *x*-ray apparatus to avoid the effect of *x*-rays upon the tissues except by carefully avoiding undue exposure. That this can be done has been demonstrated by the experience of myself and my assistants, none of whom has ever suffered in any way from the slightest *x*-ray burn. No precaution of any sort has been taken except to avoid unnecessary exposure to the rays. The habitual practice of testing tubes by the use of one's hand is particularly liable to lead to chronic *x*-ray burns. This is not necessary, and the habit should not be contracted.

* Am. Pract. and News, 1900, xxix, p. 361.
† American X-ray Jour., 1898, iii, p. 453.

CHAPTER VII.

INDICATIONS FOR THE THERAPEUTIC USE OF X-RAYS.

FREUND,* I believe, was the first to offer any generalization upon this subject. He suggested the use of *x*-rays (*a*) in mycotic dermatoses; (*b*) in affections of the skin in which removal of the hair is of importance to the cure; (*c*) in certain affections where its use was empirical. Among the diseases in which he suggested its use were lupus vulgaris, the various bacterial diseases of the skin, sycosis, acne, folliculitis, furunculosis, hypertrichosis, favus, various forms of tinea, and lupus erythematosus.

With the fuller information before us now a much more accurate statement of the therapeutic indications can be made. The effects of *x*-rays which offer possibilities of therapeutic application are as follows: (I) Their effect in causing atrophy of the appendages of the skin; (II) their destructive action upon organisms in living tissues; (III) their stimulative action upon the metabolism of tissues; (IV) their power of destroying certain pathological tissues; (V) their anodyne effect.

It is readily seen that such a group of indications offers great possibilities of application. It is also evident that in many affections more than one of the actions of the agent may come into play.

As a corollary to the above it may be stated broadly that *x*-rays offer a possibility of use in the following groups of affections:

I. Conditions where it is desired to remove hair: (*a*) hypertrichosis, (*b*) sycosis, (*c*) favus, (*d*) tinea tonsurans, (*e*) tinea barbæ or tinea sycosis.

II. Where it is desired to cause atrophy or diminution in size or functional activity of the sebaceous glands: (*a*) comedo, (*b*) acne, (*c*) acne rosacea, (*d*) lupus erythematosus (?).

* Wien. klin. Wochenschr., 1900, xiii, p. 827.

III. Where it is desired to cause atrophy of the sweat-glands: (*a*) hyperidrosis.

IV. It is possible that they might be of use also where one wanted to cause exfoliation of the nail substance, but as far as I know such an application of *x*-rays has never been made. I do not know either that they have ever been tried in hyperidrosis, but as a deduction from their effect upon the sweat-glands, I have previously suggested * their use in intractable forms of hyperidrosis.

V. Their destructive effect upon bacteria in tissues, of course, comes into play in a number of the affections in which their use is suggested above. Such a quality offers possibilities of the widest application in bacterial diseases of the skin. Their use in lupus vulgaris is the most brilliant application in bacterial diseases which has yet been made. But in this condition, doubtless, their effect in destroying tissues of low resistance is of greater moment than the germicidal effect. Other bacterial diseases in which they have been used successfully, and in which this characteristic is an important factor, are sycosis, acne, various forms of tinea and favus, and eczema (?).

VI. Their stimulating effect upon the metabolism of the skin offers a wide field of application. It is probably this effect that explains the success that has followed their use in chronic indurated eczema, lupus erythematosus, lichen planus, psoriasis, and in fact in the entire class of indurated, inflammatory diseases of the skin in which stimulation of the tissues is necessary in order to cause absorption of inflammatory products.

VII. Their power of causing the destruction of tissues of low resistance without the destruction of the healthy stroma is the theoretical indication for their use in various malignant diseases and in other processes in which we have to do with cells of low resistance. Such a group includes, of course, most important affections; as carcinoma and sarcoma, tuberculosis, pseudo-leukemia, and leukemia.

VIII. Their anodyne effect comes into play in the treatment of painful malignant and inflammatory conditions, in neuralgias

* Jour. Am. Med. Assoc., 1901, xxxvii, p. 820.

and in itching dermatoses. In the neuralgias which have been reported as relieved by *x*-rays it is probable that this quality of the agent alone has been active.

It is, of course, impossible that any such classification as I have attempted above can be comprehensive and entirely accurate. No classification can be entirely satisfactory until our knowledge of the pathology of disease becomes absolute, and that day is far off. The attempt at classification has been made in order to show in a general way the possible fields of application of the agent. It is a remark one constantly hears that the use of *x*-rays as a therapeutic agent is entirely empirical; that in working with them, we are working in the dark, and that there are as yet practically no definite indications for their use. I believe there is no therapeutic agent against which such a charge can less justly be brought. Observation of their clinical effects, and microscopic studies of tissues under the influence of *x*-rays, have furnished us rational indications for their use which are definite and positive. There is no therapeutic application of *x*-rays which has been successfully made that is not in consonance with our present knowledge of their effect upon tissues. Their use as a therapeutic agent is, in fact, much less empirical than the use of quinin or mercury or arsenic or many other of our most useful remedies. We have some knowledge of what changes take place in the cells under *x*-rays, and no man can yet offer as accurate a description of the changes in the cells produced by arsenic or mercury or quinin.

As to the limits of usefulness of *x*-rays, our knowledge is as yet far from complete. Only time can definitely settle such questions. He would be a rash man who would make any dogmatic statements upon this point, but within certain broad limits speculation is possible. It will probably prove true in the end that *x*-rays can only be curative in affections circumscribed sufficiently to get direct effect of the rays upon the pathological tissues without causing destruction of the overlying and surrounding healthy tissues. *X*-rays will probably prove ineffectual against widely distributed metastases of malignant diseases. There has been some suggestion that the

destruction of the cells of malignant growths and other pathological processes liberates toxins or antitoxins which may be effective against other foci of disease. There is nothing as yet to prove that such is the case. We are not, however, in position to dogmatize as to the limits of depth at which *x*-rays may be effectual against malignant growths. Some well-established findings upon this point are extraordinary and justify the persistent attempt to use *x*-rays in processes which are apparently beyond hope. Before we determine the full limits of usefulness of the agent, there will be doubtless many disappointing results. There is reason to hope that there will also be some encouraging ones.

CHAPTER VIII.

DISEASES OF THE APPENDAGES OF THE SKIN.

Hypertrichosis.—One of the first scientific efforts to use *x*-rays for therapeutic purposes was the attempt by Freund * to remove the hairs from a large hairy nævus by their use.† This first attempt was in a measure successful, and it led to his subsequent recommendation of the method for the treatment of hypertrichosis.

There are now many reports in the literature of the successful removal of hair by *x*-rays, but the time that has elapsed between

* Wien. med. Wochens., 1897, xlvii, p. 428.

† The queston of priority in the therapeutic application of *x*-rays has been, like most other questions of priority, a matter of contention. The facts in the case seem to be these :

Despeignes, 1896 : La Semaine Médicale, July 29, 1896, xvi, p. cxlvi, under the title "Cancer de l'estomac amelioré par l'emploi des rayons de Röntgen," says : "Dr. Despeignes has had occasion recently to treat by *x*-rays a patient affected with cancer of the stomach. This patient was exposed twice a day to the *x*-light, each sitting lasting a half hour, during which the rays from a pear-shaped tube were directed upon the gastric neoplasm."

Freund, Jan. 15, 1897 : At a meeting of the k. k. Gesellschaft der Aerzte at Vienna, Jan. 15, 1897, Freund gave his first report on the *x*-ray treatment of a nævus pigmentosus pilosus. This report was published in the Wiener medizinische Wochenschrift, Mar. 6, 1897, xlvii, p. 428. In this article Freund stated that he and Schiff were about to undertake further experiments on the effect of *x*-rays upon the other conditions of the skin. In a subsequent report on the same case (Wien. med. Wochens., May 18, 1897, xlvii, p. 856), Freund suggested the use of *x*-rays in sycosis and favus.

Rendu and Du Castel, Jan. 17, 1897 : Rendu and Du Castel, Bullétin Médicale, Jan. 17, 1897, reported the employment of the *x*-rays, at the request of the patient's father, in a case of bronchopneumonia ; 55 sittings were given, with apparently favorable result.

Kümmell, April 22, 1897 : At the twenty-second Congress of the Deutsche Gesellschaft für Chirurgie, April 22, 1897, Kümmell reported the results obtained by himself and his associate, Gocht, in lupus. This report was embodied in his article, "Die Bedeutung der Röntgenstrahlen für die Chirurgie," published in the Centralblatt für Chirurgie, July 17, 1897, xxiv, Beilage p. 18.

Schiff, Aug. 25, 1897: At the Twelfth International Medical Congress at Moscow, Aug. 25, 1897, Freund reported his experiments on the removal of hair by

the removal of the hair and the reports in many cases is not sufficient to allow of conclusion as to the permanency of the results. Reports of results more or less successful have been made by Schiff and Freund,* Benedikt,† Walsh,‡ Ehrmann,§ Sharp,‖ Wood,** Meek,†† Startin,‡‡ Hahn,§§ Sjögren and Sederholm,‖‖ Gocht,*** Beck,††† Török and Schein,‡‡‡ Jutassy,§§§ and others.

Schiff and Freund, to whom is due the credit of the introduction of the method, reported in 1898 six cases treated successfully by this method. Their conclusions from these cases were briefly as follows:

The best results are obtained after seventeen to thirty exposures. The only signs of reaction produced are a slight temporary erythema or pigmentation occurring shortly before

x-rays; and in his report he included at Schiff's request a report on Schiff's treatment of lupus, stating that Schiff's article on the subject would appear later.

Gocht, Sept., 1897: In the first number of the Fortschritte an dem Gebiete der Roentgenstrahlen, the date of publication of which is given by the editors as September, 1897, Gocht published a fairly comprehensive article on the x-ray treatment of six cases of lupus, two cases of mammary cancer, one case of nævus pilosus, one case of trigeminal neuralgia, and one case of removal of hair from an obstinate wound. He stated in this article that Dr. Kümmell had already reported their experiments at the Surgical Congress of that year.

For real priority in the whole field of phototherapy and radiotherapy it seems, however, that we must go back about five hundred years, according to the following statement from the Polyclinic for April, 1902 (N. Y. Med. Jour., 1902, lxxvi, p. 766).

"So early as the fourteenth century John of Gaddesden, the author of the treatise 'Rosa Medicinæ,' treated the son of King Edward I for variola by enveloping him in a robe of scarlet and placing him in a bed hung with scarlet curtains, in a room also curtained in scarlet. The patient recovered without any marks of smallpox."

* Wien. med. Wochens., 1898, xlviii, p. 1058.

† Wien. med. Wochens., 1901, li, p. 517. ‡ Lancet, 1901, ii, p. 1191.

§ Wien. med. Wochens., 1901, li, p. 1466.

‖ Archives of the Röntgen Ray, 1900, iv, p. 52. ** Lancet, 1900, i, p. 231.

†† Boston Med. and Surg. Jour., 1902, cxlvii, p. 152.

‡‡ Lancet, 1901, i, p. 651; and 1901, ii, p. 1375.

§§ Wien. med Wochens., 1901, xxvii, V. B. p. 29.

‖‖ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.

*** Fortschr. a. d. Geb. d. Röntgenstrahlen, 1897, i, p. 14.

††† Med. Record, 1902, lxi, p. 83.

‡‡‡ Wien. med. Wochens., 1902, lii, p. 847.

§§§ Ungar. med. Presse, 1898, iii, p. 33.

the falling of the hair and vanishing in three or four days. In some brunettes the hair becomes snow-white before falling out.

In a further report in 1900 * they state as a result of their experience that the treatment "frees surfaces from growths of hair, no matter how thick, within a few weeks, and completely, thus offering at the beginning of treatment a result obtained by means of electrolysis only after years of trouble. The secondary treatment is intermittent and requires the presence of the patient only at definite intervals for a few days. For small hairy warts and moles we give the preference to electrolysis; for large surfaces, however, unhesitatingly to the *x*-rays."

Holzknecht † has reported favorable results in hypertrichosis with a close or heavy growth of hair. He does not recommend the treatment for young persons with a fine growth of hair, on account of the atrophy of the skin which is caused.

Jutassy has reported forty cases treated by this method, and concludes from his experience that permanent alopecia may be attained. Some of his cases have shown no recurrence after a year. Lasting alopecia may be expected, in his opinion, only after repeated production of the condition of hyperemia.

Neville Wood reported one case of removal of thick dark hairs from the chin, in which eight months after the cessation of treatment parts which had had dermatitis remained quite free from hairs.

Startin reported four cases of hypertrichosis successfully treated by *x*-rays. Eighteen months later he reported that there had been no recurrence in any of these cases. And he reported, further, that he had treated forty other cases of hypertrichosis which are "as nearly relieved as can be." In each of these cases there had been slight dermatitis.

Sjögren and Sederholm have reported the treatment of ten cases of hypertrichosis, and conclude that there is no question that repeated exposures will destroy the hair follicles, the practicability of the treatment depending upon the size of the area to be affected. For a comparatively small number of hairs some other method is preferable.

* Wien. klin. Wochens., 1900, xiii, p. 827.

† Havas: Arch. f. Derm. u. Syph., 1900, Festschrift Kaposi, p. 275.

I have treated fourteen cases of hypertrichosis by this method as follows:

Case 1.—Miss ———, aged twenty-five, with dark hair and fair skin, with profuse growth of dark hairs on both arms. Began treatment February 1, 1900. She had thirty-eight exposures on either arm between February 1 and March 17. On March 19 there was some burning and irritation "like sunburn." A few days later mild dermatitis developed which subsided in the course of a week, and with its disappearance the hairs on the back of the arms came out. Against her wishes she was unable to have further treatment, and there was a recurrence of a great part of the growth, though the condition is improved.

Case 2.—Miss ———, aged twenty-two, with black hair and moderately fair skin. There was a profuse growth of very coarse black hairs on the chin and upper lip. The growth under the chin practically amounted to a beard, and was not less than that seen in many men of the same age. During July, August, and September, 1900, she received forty sittings. After twenty-five sittings slight erythema appeared, which subsided after a few days' respite from treatment. This erythema recurred twice and quickly subsided each time. It was noted that the first evidence of reaction was always the turning white of the hairs. After the development of the first erythema the hairs began to come out. During November and December she received twenty-five treatments, and on December 14 an acute dry dermatitis developed. The skin became quite tender, but the dermatitis subsided without vesiculation at the end of two weeks, and with its subsidence practically all of the hairs came out. Since that time, January, 1901, there has never been a marked return of hair, though a few hairs recurred, and at intervals of three to five months she has had a few exposures for the removal of recurrent hairs. She had ten exposures in February, 1902, to remove a few remaining hairs on her chin. Since January, 1901, there have been practically no disfiguring hairs on her face, and there has never been at any time return of more than a few hairs. The result in this case may be regarded as entirely satisfactory, though it was

attained at the expense of an irritation which at the time of its occurrence caused me much anxiety.

Case 3.—Mrs. ———, aged thirty-five, with brown hair and moderately fair skin and with a profuse growth of long, coarse hairs under the chin and on the upper lip, and down over the cheeks. Treatment was begun August 1, 1900. Between August 1 and November 27 sixty-six exposures were given. During this time slight erythema developed on several occasions, accompanied by the outfall of some hair. A rest for the erythema to disappear was allowed at each time of its occurrence. By January 1, 1901, the face was practically free from hair. There was slight pigmentation and slight wrinkling of the skin around the corners of the mouth. By June, 1901, there had been a considerable return of hair, and in July and August, 1901, she had fifteen sittings for the removal of these hairs. Since that time she has had two series of exposures of ten to fifteen sittings each, but at present there is some recurrence of hairs. In this case the hairs began to recur before the entire disappearance of the pigmentation. At the present time there is a considerable return of hair and the case cannot be called a success. The number of hairs is very considerably diminished, sufficiently so to satisfy the patient, but the result is not satisfactory. The slight erythema and pigmentation in this case at one time persisted for several months.

Case 4.—Miss ———, aged twenty-five, with dark hair and medium complexion. This patient was a niece of the patient in Case 3, and the course and result of treatment were almost identical. The growth of hair was not so marked and the result is somewhat better, but there has been some return of hair. This case was treated at practically the same time as Case 3, and has had no treatment since January, 1902.

Case 5.—Miss ———, aged twenty-eight, with fair hair and medium complexion. She had a growth of long coarse hairs, many of them more than an inch long, under the chin, and a similar growth not so marked on the upper lip and cheeks. Treatment began October, 1900. After thirty-three exposures some dermatitis developed, and the hairs came out in December,

1900. By the middle of February, 1901, some hairs had recurred and were removed in twelve sittings. By the middle of June some hairs had recurred again, and were removed in fifteen sittings. By the middle of November, 1901, a considerable number of hairs had recurred and were removed in twenty sittings. In March, 1902, there had been some recurrence of hairs and she was given eleven sittings. These exposures were followed by a rather acute weeping dermatitis, although the previous treatments had never been accompanied by more than a moderate dry dermatitis and had produced practically no pigmentation. This dermatitis disappeared in six weeks, but the patient had two subsequent slight returns of dermatitis over this area. The face at the present time is free from hair except for a few inconspicuous short hairs under the chin. The condition of the skin is slightly atrophic around the sides of the chin, but not conspicuously so.

In the succeeding cases the treatment has been carried out in much the same way as in those given above as regards the number of exposures, the repetitions of treatment, and the intensity of the light. Therefore these details will not be repeated.

Case 6.—Mrs. ———, aged thirty-five, with brown hair and medium complexion, and with a profuse growth of not very coarse hairs under chin and on upper lip. Treatment in this case began in January, 1901. She has been treated persistently, with removal of the hair on three occasions. There has always been considerable return of hair, however, and the removal of the hair has been accompanied by a good deal of pigmentation. There is some improvement in the hypertrichosis at present, but the return of hair has been considerable, and the result cannot be regarded as satisfactory.

Case 7.—Miss ———, aged twenty-six, with black hair and dark skin, and with abundant growth of long, coarse, black hairs under the chin, on the upper lip, and on the cheeks. This patient began treatment in January, 1901. In the reaction to *x*-rays this case has been markedly similar to Case 6. The hairs on the cheeks and upper lip are no longer sufficient to be disfiguring, but there are still some coarse hairs that tend to recur under the chin.

Case 8.—Mrs. ———, aged forty-eight, with black hair and dark skin, and with a very abundant growth of coarse black hairs on upper lip, chin, and cheeks. The hypertrichosis in this case was excessive; the hairs were very coarse and black, and under the chin were an inch or more long. Treatment was begun April 29, 1901, and the hair was satisfactorily removed. She has had several subsequent series of exposures. After each removal there has been some recurrence of coarse hairs, but their number has gradually diminished. At present there is a return of a few hairs, but their number is much less. This patient, without having at any time a marked dermatitis, has shown a good deal of pigmentation, and there has been considerable wrinkling of the skin. The present condition, while a decided improvement, cannot be called a satisfactory result.

Case 9.—Miss ———, aged thirty, with dark hair and fair skin and with an abundant growth of long down over the cheeks and under the chin. The patient was treated during the summer of 1901 with satisfactory results. All of the hairs from the cheeks and under the chin disappeared without a severe reaction being produced, and although the patient had no treatment from September, 1901, to June, 1902, there was only the return of a small amount of down on the cheeks, not sufficient to cause annoyance. There was during the summer of 1902 a return of a few hairs under the chin, which were removed.

Case 10.—Miss ———, aged twenty-five, with dark hair and fair skin, and with down on upper lip and cheeks. This case had more persistent treatment than No. 9, but in its course and in its results is very similar. Treatment was begun in May, 1901. The hairs were removed satisfactorily over all the areas in October, 1901. She has had several periods of treatment since that time, but there has been no marked recurrence of hair, and there is only a very small quantity of down upon the face.

Case 11.—Miss ———, aged twenty-six, with light brown hair and medium complexion, and with growth of long, coarse, light brown hairs under chin, and down on upper lip and cheeks.

Treatment began June, 1901, and the hairs were removed, in this case in the summer of 1901, and have not shown marked tendency to recur. She has had several periods of treatment since that time. At present, after four months without treatment, there is a slight recurrence of hair on the upper lip, but at no time has there been a marked recurrence of the down on the cheeks, or of the long hairs under the chin, where the treatment was most vigorous.

Case 12.—Mrs. ———, aged forty-two, with dark hair and fair skin and with growth of fine hairs under chin and on upper lip. This case is very similar to Cases 9 and 10. Treatment began in October, 1901, and the hairs were satisfactorily removed. There has been no treatment since March, 1902, and the condition is distinctly improved, while there is still some down.

Case 13.—Mrs. ———, aged fifty, with dark hair and medium complexion and with abundant growth of fairly long hairs under the chin, and profuse growth of long down on upper lip and cheeks. The case is very similar to Case 11. The treatment in this case has been accompanied by a gradual shedding of the hair, but there has been at times considerable pigmentation and always some recurrence of hairs. At the present time the condition of hypertrichosis is somewhat improved, but not markedly so. The general condition of her skin is distinctly improved.

Case 14.—Mrs. ———, aged thirty-eight, with dark hair and fair skin, and with a considerable growth of down on chin and cheeks and upper lip. This was removed in February, March, and April, 1902, and has shown only slight tendency to return, except on the upper lip, which is but little improved.

In this connection I may mention the removal of the hairs from a large pigmented hairy nævus over the right eye of a baby. In this case the hair was satisfactorily removed, leaving an eyebrow of good shape. There has been only a slight tendency to recurrence, the pigmentation has been greatly diminished, and the skin is smooth and normal-looking.

As will be seen, the results in these cases are not uniform. Case 2 may, I think, be put down as an unqualified success.

Case 5 also shows a satisfactory result. Case 1 shows improvement, but there were not enough treatments to give the method a fair trial. Cases 9, 10, 12, and 14, all of which showed very slight degrees of hypertrichosis, have shown distinct improvement, and the results are satisfactory to the patients, the most critical judges in such cases. Case 11 has been distinctly improved, and Case 12 also improved, though to a less degree. In Case 8 there has been a marked decrease in the number of hairs, but those that remain are still distinctly conspicuous, and whether or not the result justifies the treatment is in my mind a matter of doubt. Cases 3, 4, 6, and 7 have not shown sufficient improvement, in my opinion, to justify the treatment.

The condition in which the skin of the parts treated has been left is worthy of brief consideration. In Cases 2, 11, and 13 the appearance of the skin, aside from the removal of the hair, has been distinctly improved. In Case 11 there was a severe acne of the chin, which has not recurred in a year. None of these cases shows more than very slight atrophy of the skin around the corners of the mouth, and this is not noticeable. In Cases 9, 10, 12, and 14 all the patients had good complexions at the time treatment was begun, and this condition has not been changed by the treatment. In Case 12 there was noted the appearance of two or three faint wrinkles at the corners of the mouth. In Cases 3, 4, 6, and 7 decided pigmentation occurred, which for a time was apparent, but not more conspicuous than the ordinary tan of summer. The skin of the chin in Case 3 showed for several months considerable irritation. In Case 8 the wrinkling of the skin as the result of the removal of so many coarse hairs is quite perceptible, and is sufficient to be given some weight in considering the result. In Case 5 the skin remained quite irritable for several months after the dermatitis, with two recurrent attacks of acute dermatitis which were for a time very annoying. The permanent condition of the skin in this case, though there is slight atrophy, is not unsatisfactory, and, taken in connection with the disappearance of the hair, is a great improvement.

It is evident that the reaction required to cause removal of the hair has varied very considerably in different individuals.

In Cases 1, 3, 4, 6, 7, 9, 10, 11, 12, 13, and 14 there has never been more than slight dry dermatitis In some of these cases it has been very slight, but I have never seen the hairs disappear in any case without the production of some erythema, and I have made persistent and patient attempts to attain the outfall of the hair without any inflammatory reaction. In Cases 2 and 5 quite acute dermatitis was produced, and the results in these two cases are more radical than in any others. My experience is in accord, therefore, with those writers who report that to get alopecia some dermatitis is required, and that the result is more permanent when the dermatitis is considerable.

From my experience I am of the opinion that the treatment of hypertrichosis by the use of *x*-rays is only a qualified success. I think, from the consideration of my cases and other cases in the literature, that there can be no question that hair can be permanently removed in some cases by repeated *x*-ray exposures without damage to the skin. On the other hand, it is probable that in some cases a satisfactory result cannot be obtained. It is an indisputable fact that in addition to the removal of the hair there will be a distinct improvement in the skin in some cases. This is particularly noticeable where the skin is profusely supplied with sebaceous glands. The slight atrophy of the skin that accompanies the successful removal of hairs is in a few cases of sufficient extent to detract somewhat from completely satisfactory cosmetic results, but in most cases this is not important. I have not found, as Holzknecht suggests, that this atrophy is of more importance in young patients than in older ones. Indeed, the only atrophy that I have seen that is worthy of mention has been in my oldest patient.

Considering the difficulties in the way of carrying out this treatment, it is to be recommended only in those cases in which a large number of hairs need to be removed Where only a few hairs are to be removed electrolysis is the better method. Electrolysis, however, is notoriously inadequate for the removal of a profuse growth of hair, and in such cases the use of *x*-rays is to be considered. The method is so tedious and so beset

with difficulties that I hesitate to advise it except in cases of hypertrichosis of exaggerated type. There is, however, in my opinion no objection to its application in any case, however slight, in which the patient is urgent for relief. The greatest difficulty in connection with this treatment of hypertrichosis is that one is treating a purely cosmetic defect, and therefore must stay well within the bounds of safety. But to cause a sufficient atrophy of the hair follicles to produce alopecia a very considerable *x*-ray effect must be attained, and to do this without causing an undesirable degree of dermatitis is a problem of the greatest nicety. There is no therapeutic application of *x*-rays, I am sure, which requires so much caution and skill as does the removal of hair. And I believe one should not undertake it until he has had considerable experience with his particular apparatus in the treatment of other affections.

Alopecia Areata.—The treatment of alopecia areata by *x*-rays has been reported by Kienböck * and Holzknecht.† Kienböck has reported a case in a young man, of three years' duration, in which two months after *x*-ray exposures dark-colored normal hairs appeared on the surface treated, while on surfaces that had not been treated the growth of hairs did not occur.

Holzknecht has used the method with some success in several cases. One case he has described: A boy aged eighteen had alopecia areata that had progressed steadily for five months. There was a fine growth of hair after six months' treatment with *x*-rays.

Alopecia areata is a disease so irregular in its course that one must be very cautious in drawing conclusions as to the utility of any method of treatment. In the cases of alopecia areata which are mycotic in origin—and in all probability there are many such cases—it is possible that *x*-rays may prove of use, and in cases of tinea tonsurans simulating alopecia areata this treatment would probably be successful. In the cases which are not mycotic—and in the light of our present knowledge probably many of them are not—it is hard to say how *x*-rays

* Wien. klin. Wochens., 1900, xiii, p. 1053.
† Wien. klin. Wochens., 1900, xiii, p. 1177.

could be of any more service than other stimulants. The fact, however, that *x*-rays cause temporary atrophy of the follicles is not a valid reason for believing that they would be contra-indicated in alopecia areata, for unless an *x*-ray reaction is produced several times the healthy hair follicles regenerate. It is barely possible that the effect of *x*-rays upon the tissues in alopecia areata would tend in the end to a regeneration of the hair follicles. All this, however, is speculation, and it will require a very much larger experience in alopecia areata than we yet have to furnish a basis for any opinion as to the use of *x*-rays in that disease.

Tinea Tonsurans and Favus.—The use of *x*-rays in the treatment of tinea tonsurans and favus was suggested by Freund.* Cases of tinea tonsurans, successfully treated by *x*-rays, have been reported by Schiff and Freund,† Kienböck,‡ Török and Schein,§ and others. Cases of favus successfully treated have been reported by Schiff and Freund,† Hahn and Albers-Schönberg,‖ Török and Schein,§ Kienböck,‡ and others. One of Schiff and Freund's cases has remained cured for a year. In these cases the reaction has to be carried to the point of causing complete alopecia and slight inflammatory reaction of the skin. Theoretically the treatment is ideal. It causes outfall of the diseased hairs, and at the same time destroys the organisms upon which the disease is dependent. The alopecia which it causes is temporary unless it is accompanied by a greater reaction in the skin than is necessary. The practical objections to the method are, in the first place, that it is tedious; and, in the second, that *x*-ray exposures of as large a part of the scalp as is necessary in the treatment of the usual case of tinea tonsurans or favus is a procedure of some risk unless carried out with caution.

All that is said concerning the method in the treatment of tinea tonsurans applies with equal weight to the treatment of favus.

* Wien. med. Wochens., 1897, xlvii, p. 856.
† Fortschr. a. d. Geb. d. Röntgenstrahlen, 1899, iii, p. 109.
‡ Arch. f. Derm. u. Syph., 1901, lvi, p. 132.
§ Wien. med. Wochens., 1902, lii, p. 847.
‖ Münch. med. Wochens., 1900, xlvii, pp. 284, 324, 363.

The method may prove a very much needed addition to the therapy of these diseases.

Sycosis.—The treatment of sycosis by *x*-rays was suggested and first carried out by Schiff and Freund,* and there are numerous reports in the literature testifying to its success. Successful cases have been reported by Hahn,† Spiegler,‡ Rinehart,§ Scholtz,‖ Gassman and Schenkel,** Török and Schein,†† and others. The treatment has proved equally efficacious in parasitic and non-parasitic sycosis. In some of the cases the patients have remained well a year after the cessation of treatment. A typical successful case of parasitic sycosis is that reported by Zechmeister.§§ In this case the face was covered with deep follicular pustules. Hyphomycetes had been demonstrated around the roots of the hairs. After five strong exposures there was slight reddening and scaling of the pustules. Ten days later the pustules had vanished, and in two weeks more the disease had entirely disappeared. Three months later the patient was still well.

A successful result in non-parasitic sycosis is shown in the following case treated by me:

Case 15.—Man, aged thirty-five, street-car driver, referred to me by Dr. Henry F. Lewis, of Chicago. His condition at the time he came under my care is shown in figure 104. The case was a simple sycosis of moderate severity; there was no ringworm fungus present. The skin was indurated and boggy, with gaping hair follicles filled with pus, and at one point there was a mass of exuberant granulations, forming a tumor the size of a mulberry. The disease had persisted for eight months in spite of vigorous local treatment. After coming under my charge the case was given no local treatment except that the patient was told to wash off the surface twice a day with soap

* Wien. med. Wochens., 1897, xlvii, p. 856. Fortschr. a. d. Geb. d. Röntgenstrahlen, 1899, iii, p. 109.

† Deut. med. Wochens., 1901, xxvii, V. B. p. 29.

‡ Arch. f. Derm. u. Syph., 1901, lvi, p. 131.

§ Phila. Med. Jour., 1902, ix, p. 221.

‖ Arch. f. Derm. u. Syph., 1902, lix, p. 421.

** Fortschr. a. d. Geb. d. Röntgenstrahlen, 1899, ii, p. 121.

†† Wien. med. Wochens., 1902, lii, p. 847.

§§ Monatsheft f. prakt. Derm., 1901, xxxii, p. 329.

and to protect it with cloths spread with boric acid aselin. He was put under *x*-ray exposures November 4, 1901, t there was practically no improvement up to the middle of January. At that time a very slight dermatitis was pro- d. The sittings were cautiously continued until the der- atis became rather acute, and on January 23 they were ontinued. By February 1 there was complete alopecia over exposed area. After the appearance of the erythema there was rapid improvement in the sycosis, and by February 1 all idence of disease had entirely disappeared. The mass of exuberant granulations referred to above had shrunken until it was almost on a level with the skin, and was covered with healthy epidermis. The condition on February 1, 1902, is shown in figure 105. The beard removed has since returned, and the disease has not recurred in ten months, so that a cure has been produced.

In sycosis the reaction has to be carried to the point of pro- ducing complete outfall of the hairs and enough reaction in the skin to destroy the pus organisms and mycelia and spores. In all the cases reported it has required the production of a dermatitis. As under ordinary circumstances there is reason to fear that the hairs removed will not in time return, the method offers a distinct advantage over any other method that we now have for treating sycosis, whether parasitic or non-parasitic. It is not to be recommended in place of satisfactory methods of treatment already at our command in impetigo or impetiginous eczema of the bearded part of the face, both of which are so frequently confused with sycosis.

Acne Vulgaris and Comedo.—The use of *x*-rays in acne is indicated upon the same grounds as their use in sycosis. The two qualities of *x*-rays which come into play in the treatment of acne, and of sycosis as well, are, first, their property of causing atrophy of the glands of the skin—the sebaceous glands as well as the hair follicles; and, second, their property of destroying bacteria in the skin and inhibiting the formation of pus. Numerous workers have reported upon the use of *x*-rays in acne. Jutassy * has noted the cure of acne in cases which

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1900, iii, p. 119.

Fig. 104.—Sycosis.

Fig. 105.

were under treatment by *x*-rays for other cutaneous troubles. Pakhitonov * has reported a case of ten years' duration which was treated successfully by *x*-rays. Gautier † has reported fifteen cases of acne vulgaris and acne rosacea in which there has been great improvement. He used a rather strong light for five or six minutes daily, at a distance of 30 cm. Good effects became apparent after the sixth sitting. Sjögren and Sederholm § have reported a severe case almost completely cured by *x*-rays, the pustules and comedones disappearing with the passing of the reaction. Török and Schein ‡ have had three cases of acne in which good results were obtained as long as they were under treatment. The formation of pustules and comedones ceased and the skin became smooth. One case had been free for three months at the time of the report. In one case under treatment the upper half of the chin became pigmented and the acne became worse, improving after six weeks. Scholtz ‖ states that acne vulgaris, in his experience, has been much improved by *x*-ray treatment, but not to such an extent as to make this treatment preferable to all others. The papules and comedones disappear, but new ones sometimes appear even during the treatment. Campbell ** reported fifteen cases which were cured or improved by *x*-ray exposures alone. It will thus be seen that the testimony as to the benefit of *x*-ray exposures in acne is practically unanimous. My own experience in acne covers fourteen cases in which sufficient time has elapsed to allow an estimate as to the permanency of the results. As briefly as possible they are as follows:

Case 16.—Miss ———, aged twenty-two, brunette, was put under *x*-ray exposures in July, 1900, for hypertrichosis. On the chin and around the mouth she had an acne simplex of moderate severity. The lesions were usually indolent inflammatory papules without much induration. Under the produc-

* Comptes Rendus XII Int. Cong. de Méd., p. 382.
† Comptes Rendus XII Int. Cong. de Méd., p. 385.
‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.
§ Wien. med. Wochens., 1902, lii, p. 847.
‖ Arch. f. Derm. u. Syph., 1902, lix, p. 421.
** Jour. Am. Med. Assoc., 1902, xxxix, p. 313.

tion of the first slight erythema the acne disappeared, and she has had no recurrence in two years.

Case 17.—Miss ———, aged twenty-six. This case is identical in all essential details with Case 1. The patient began treatment January, 1901, and has had no acne since the production of the first slight erythema—two years ago.

Case 18.—Miss ———, aged twenty-six, with yellowish-white skin. She had suffered for a long time with a slight acne about the chin, with numerous comedones and constantly recurring outbreaks of a few indolent inflammatory pustules. She had been more or less constantly under my treatment for several years for this acne and I had never succeeded in entirely relieving her of it. Since the production of the first erythema, in September, 1901, she has had no acne lesions.

These three cases have been under observation continuously. Cases 17 and 18 have had *x*-ray exposures at intervals, so that the effect of *x*-rays upon the skin has been maintained. In all the results are satisfactory from a cosmetic point of view. The skin is smooth and soft and of good color. There is a very slight but entirely unnoticeable atrophy of the skin in each of the cases.

Case 19.—Miss ———, aged twenty-three, with brown hair and fair skin and with moderate indurated acne of the lower part of the face and forehead. Ordinary methods of treatment failing after six weeks' trial, I suggested *x*-rays in view of the favorable results in the foregoing cases. She was given *x*-ray exposures with a very weak light for a month in August and September, 1901, receiving eighteen exposures in all. Improvement was apparent within two weeks, and after a month there were no active lesions present. At no time was an erythema produced. There was no recurrence, but between December 21, 1901, and January 3, 1902, she had ten prophylactic treatments without the production of erythema. After this, without treatment, there occurred an occasional single small papule, but she was practically free from the disease until the middle of the summer of 1902. At that time there was a slight recurrence, and she had further exposures with marked improvement. The case has been improved until the only trace of the disease

is an occasional appearance of a single lesion. Previous to the treatment with *x*-rays there had been no time within twelve months when she had not had numerous pustules and papules about the face.

Case 20.—Miss ———, aged twenty-three, light brown hair and yellowish, pasty skin, was referred to me by Dr. Moreau Brown, of Chicago. This was an unusually severe, deep-seated, indurated acne of two years' duration, with a great number of pustules and many scars. She was under *x*-ray exposures more or less regularly from September 16 to December 30, 1901, receiving in all twenty-nine exposures. After December 1 she was practically free from acne. The improvement in this case can hardly be exaggerated. The patient now has a clean, healthy-looking skin; there are, of course, numerous scars left, but no other traces of acne.

Case 21.—Miss ———, aged twenty-two. This was an acne simplex of moderate severity under the chin and about the face in a young woman with a sluggish skin. It was greatly improved under *x*-ray exposures between December 14, 1901, and February 27, 1902. Without further treatment she remained well for several months, but in October, 1902, she returned with some recurrence.

Case 22.—Miss ———, aged sixteen, with black hair and fair skin. This was a typical extremely severe juvenile acne with a great number of comedones and superficial pustules. The disease had existed for two years practically unchanged in spite of constant treatment. Between January 2 and March 31, 1901, she had fifty-three exposures, with the entire disappearance of the acne and practically entire disappearance of comedones. The improvement in this case is remarkable and is such as I have never seen from any other treatment of a similar case. She is free from acne and comedones and the skin is of good color. Eight months later she remains well.

Case 23.—Mrs. ———, aged thirty-five, with dark hair and fair skin, spare built, anemic, with constantly appearing papules about the face and chin and a few comedones. This patient has been under my care at times from January 2, 1902, to date. Under the first series of *x*-ray exposures the acne was greatly

improved. From February to May, 1902, she had no exposures. There was a recurrence of a few acne lesions in the mean time. During the past summer [1902] she had fifteen exposures in two months with decided improvement in her condition. She still has, however, at times, outbreaks of a few acne lesions.

Case 24.—Miss ———, aged twenty-four, with dark hair and fair skin. For five years she had had a very severe, indolent, deep-seated acne. The skin was pale and sluggish and the cheeks were covered with dark red, deep-seated, indolent lesions, which would remain for weeks without the formation of a well-developed pustule. Between January 2 and March 31, 1902, she had forty-five exposures with complete disappearance of the acne. The improvement in this condition could hardly have been greater. I believe she remains well now, eight months after stopping treatment.

Case 25.—Miss ———, aged eighteen, referred to me by Dr. D. A. K. Steele, of Chicago; a healthy, vigorous young woman with a moderate but very persistent juvenile acne. There were not many comedones but there were constantly recurring groups of indurated papules without much elevation and very slow to disappear. The patient has been under the care of many excellent dermatologists without at any time disappearance of the disease. She has had exposures to *x*-rays for several periods between January and October, 1902. Her acne has at times entirely disappeared and remained well for several months, but she has occasionally one or two lesions. The improvement, however, is very great.

Case 26.—Mrs. ———, aged forty, with black hair and a florid complexion and with a severe persistent acne around the mouth and cheeks. Between January 2 and March 28, 1902, this patient had thirty-eight exposures. There was little improvement during the first two months in spite of the fact that reaction was carried to the production of slight pigmentation. At the end of the treatment there was rather an acute reaction produced which showed especially in an increase of the folliculitis. After two weeks this disappeared, and with it the acne. Since April, 1902, there has been a very great

improvement in the condition of her complexion. She still has occasionally an inflamed follicle, but is practically well.

Case 27.—Miss ———, aged fourteen, with severe juvenile acne. This case is practically a duplicate of Case 22. Under *x*-ray exposures given between January and June, 1902,—fifty-six in all,—the disease has practically disappeared. Since June, 1902, she has had no treatment and there has been almost no recurrence.

Case 28.—Mrs. ———, aged thirty-three, with dark hair and fair skin, with a severe indurated acne. The course of this case was very closely similar to that of Case 26. The lesions were intractable at the start and the exposures were carried to the point of producing an acute folliculitis, upon the subsidence of whch the acne disappeared, and from February 25 to October 1, 1902, the patient remained well. In October, 1902, she had a relapse.

The marked increase in the folliculitis without the development of much erythema in the surrounding skin was a curious fact noted in both Cases 26 and 28. A similar exaggeration of the acne before improvement is noted in a case of Török and Schein referred to above.

Case 29.—Mrs. ———, aged thirty-five, very dark hair and fair skin, with a moderate indurated acne. In this case the acne was cleaned up with scattered exposures during February and March, 1902, and she has remained practically well since that date.

The physical condition in all of these patients was about such as one usually sees in acne; digestive disturbances, usually constipation in some of them, and some of them anemic. Most of the patients were in average health. The only one that showed a marked departure from health was Case 24. This young woman had had a chronic diarrhea for several years and was very anemic; at the beginning of treatment she had 50 per cent. hemoglobin. She had internal treatment along the usual lines for such conditions while having *x*-ray exposures, with considerable improvement in her general health. When there was anemia or other indication to be met, the patients had treatment along the usual lines. Of local treatment they

had very little, for the reason that it is undesirable to run the risk of confusing an irritation of the skin such as is caused by the applications used in acne with an *x*-ray dermatitis. In accounting for the results I believe the effect of the local treatment other than *x*-rays and of internal treatment are entitled to very little weight. Almost all of the cases had failed of relief under the usual methods of treatment and the effect of *x*-ray exposures was direct and prompt, leaving no uncertainty as to the part they played in the improvement.

I think it may be safely said that in *x*-rays we have found a method of treating acne more effective than any hitherto at our command in the treatment of that most intractable affection. As to the permanency of the results, some of my cases have shown no recurrence in a year without treatment. In others there has been some relapse, but the relapses have been slight and have proved tractable to further treatment. And even if it is found that the relapses occur at times, it lessens very little the value of the method, for it still gives a satisfactory means of controlling this usually self-limiting disease. My experience shows that the results are decidedly persistent, and that we may reasonably hope entirely to cure an acne by a little treatment with *x*-rays from time to time, after the disease has once been relieved.

It has been suggested that possibly the skin might be damaged by the atrophy of the follicles produced in treating acne by this method. Unquestionably if it were necessary to carry the process to the point of causing destruction of the follicles, as in treating hypertrichosis, for example, this question would have to come into consideration. Further, if the treatment had to be carried to such a point it would lose much of its value because of the great difficulty, which is seen in treating hypertrichosis, of carrying the reaction to the point of causing destruction of follicles without damaging the skin. But in treating acne it is not necessary to carry the reaction to the point of causing more than the slightest atrophy of the follicles. To produce the effect desired it is only necessary to cause a slight reaction, a reaction sufficient to lessen somewhat the functional activity of the glands but not sufficient to cause their complete atrophy.

With the slight reaction necessary in order to relieve an acne it is altogether to be expected that in time complete regeneration of the glands will occur.

Of course, in treating cosmetic difficulties like acne the greatest caution must be used to avoid untoward effects. In my cases I have constantly used a very weak light. A light that is just strong enough to show as a green glow in the tube has, in my experience, proved sufficient. With such a light exposures of five to ten minutes' duration are given with the tube at a distance of 10 to 15 cm., and these are repeated daily or every second day, or at times even less frequently. I have found no condition in which improvement under *x*-rays occurs more promptly than in acne. Many of the cases have gotten well without the production of anything more than a very slight pigmentation or the slightest erythema. In only two cases has there been produced a reaction of more than the slightest intensity.

Rosacea.—*X*-rays have also been used in the treatment of acne rosacea. Gautier * has reported good results in rosacea. Hahn † has reported two cases in which he obtained excellent results; in these cases there was no return in two years. Scholtz ‡ also reports improvement in rosacea, but not to an extent to make the treatment preferable to other methods.

I have used the method in one case:

Case 30.—Miss ———, aged twenty-nine, with a very severe rosacea accompanied by a folliculitis involving the entire flush area of the face. The nose was very red with slight hypertrophy, and there were numerous large indurated pustules on the nose and cheeks, around the mouth, and on the forehead. The disease had persisted for six years in spite of treatment. Patient suffered from chronic constipation, but was otherwise well. This patient had treatment during December, 1901, and January and February, 1902, having mild exposures about every other day. After a month there was considerable improvement in the condition, and after the fifth of March the

* Comptes rendus XII Int. Cong. de Méd., p. 385.

† Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 95.

‡ Arch. f. Derm. u. Syph., 1902, lix, p. 421.

folliculitis had disappeared. Since that time she has had intermittent treatment without at any time recurrence of acne. At no time has there been a perceptible *x*-ray effect on the skin.

There is a slight rosacea left on the tip of the nose, but otherwise the disease has disappeared. The folliculitis, which was such a marked feature of the disease, has shown no tendency to reappear in eight months, and there are only a few thin telangiectases. The skin is smooth, clean, of normal color, and altogether the improvement is remarkably great. I have certainly never seen such an improvement in any other case of rosacea of equal severity.

It would seem that the method offers a valuable addition to our means of treating the folliculitis which accompanies rosacea, and which with the perifollicular inflammation plays so important a rôle in the disfigurement caused by that disease. That *x*-rays will affect the telangiectases found in rosacea there is good reason to doubt, and it is probable that in order to get the best results the use of electrolysis or some other method to destroy the dilated blood-vessels will be a necessary addition to this method of treatment.

Hyperidrosis.—The effect of *x*-rays is perhaps less upon the sweat-glands than upon either the hair follicles or the sebaceous glands. Histological studies, however, indicate that there is some atrophy of the sweat-glands as a result of *x*-ray exposures, and there seems, therefore, some theoretical ground for believing that the use of *x*-rays may be beneficial in local forms of hyperidrosis. So far as I know, no one has attempted to use *x*-rays for this purpose, and I have not tried the experiment myself, but I believe there is sufficient ground to warrant its trial in intractable cases of local hyperidrosis, as, for instance, of the axilla or of the feet.

CHAPTER IX.

INFLAMMATORY DISEASES OF THE SKIN.

X-RAYS have been used in the treatment of a number of diseases of the skin, such as eczemas, psoriasis, lichen planus, and lupus erythematosus, in which the skin is thickened and indurated as a result of a chronic inflammatory process and in which there is need of "stimulation of the tissues in order to get rid of the inflammatory exudate."

Eczema.—Several writers have reported their results in the treatment of eczema. Ullman * recommends the use of *x*-rays in eczema, especially of the chronic indurated type. Jutassy † has reported an intractable eczema of the hands, cured by *x*-ray exposures, with no return in two years. Schiff and Freund ‡ have reported a case of chronic eczema of the beard cured in eleven exposures. Williams § has reported two cases. The first case was that of a man fifty years old, who had attacks of eczema every winter, requiring treatment by the ordinary methods for some months before relief was obtained. When applying for treatment, there was a red area on the outer part of the left arm, 15 cm. by 10 cm., rough but not moist, which itched intensely. A single exposure was given for ten minutes at 10 cm. distance, and on the following morning there was no itching and no discomfort over the part treated by the *x*-rays, and the patient had no further trouble. The second case was a chronic eczema of the back, neck, and arms, with much itching. Daily exposures for many days afforded the patient no relief.

Hahn ‖ has treated, with excellent results, thirty-five cases

* Wien. med. Presse, 1900, xli, p. 954.
† Fortschr. a. d. Geb. d. Röntgenstrahlen, 1900, iii, p. 119.
‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1900, iii, p. 109.
§ "The Röntgen Rays in Medicine and Surgery," p. 409.
‖ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, v, p. 39.

of eczema. He reports that improvement has been so rapid in some cases that in one day an eczematous surface has become normal. Itching has always ceased after a few exposures. The disease in some of his cases recurred, but disappeared on renewal of treatment. He has not found it necessary to produce any apparent reaction.

Sjögren and Sederholm * have reported ten cases of chronic eczema, in the majority of which a cure was effected. Itching was relieved in all cases. Some of them showed recurrence. One case proved refractory, and had no lasting benefit.

Albers-Schönberg † has described three cases of chronic eczema, which under *x*-rays showed an unusually rapid healing.

Hahn and Albers-Schönberg ‡ have together reported fourteen cases, with results similar to those in the cases reported by them separately.

Mackey § has reported two cases of chronic eczema which had for a time been treated unsuccessfully by ordinary methods, and which were greatly improved under short periods of treatment with *x*-rays.

Meek ‖ has reported three cases of eczema; one acute, with relief in two treatments; two chronic, one relieved in nineteen treatments, another in eighteen treatments.

Scholtz** concludes from his experience that eczema is influenced in a most satisfactory manner by *x*-ray exposures. All of his patients stated after a few exposures that itching had ceased, and in three obstinate and often recurring cases the improvement was remarkable. The moisture and redness disappeared and the scaling was lessened. He recommends the use of *x*-rays especially as auxiliary to other methods of treatment in eczema.

It will be seen that there is a good deal of evidence of the value of *x*-rays in both acute and chronic forms of eczema. There is general testimony as to the relief of the itching, in both acute

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.
† Fortschr. a. d. Geb. d. Röntgenstrahlen, 1898, ii, p. 20.
‡ Münch. med. Wochens., 1900, xlvii, pp. 284, 324, 363.
§ Brit. Jour. Dermatology, 1899, xi, p. 160.
‖ Boston Med. and Surg. Jour., 1902, cxlvii, p. 152.
** Arch. f. Derm. u. Syph., 1902, lix, p. 421.

and chronic forms. The use of *x*-rays in acute types of eczema will probably have a much more limited application than in the chronic indurated forms of that disease. It is not easy to find a reason for expecting *x*-rays to be of marked value in acute vesicular or papular eczema, beyond the effect which they would have upon the itching, unless they have some peculiar influence upon the metabolism and structure of the diseased cells, of the character of which we know nothing. There are good *a priori* grounds for expecting benefit in chronic indurated patches of eczema in which there is need for marked stimulation in order to get absorption of inflammatory products. It seems probable that the chief use of *x*-rays in eczema will be in the treatment of the intractable circumscribed indurated patches of chronic eczema. That they have a valuable field of usefulness in these cases there seems little room to doubt.

Psoriasis.—The use of *x*-rays in the treatment of psoriasis has been reported in numerous quarters.

Sträter * has reported the relief of an area of psoriasis exposed to the rays from a soft tube, while a second area exposed to the rays from a hard tube was unaffected.

Startin † has reported a case of psoriasis of the legs, arms, and body, which was relieved by usual methods of treatment, except for one obstinate patch three by six inches in size on the inside of the leg. This was exposed to *x*-rays seven times, exposure being given every three days, with the result that in two weeks after the last exposure the whole patch vanished, leaving healthy skin.

Hahn ‡ states that six cases of psoriasis treated by *x*-ray exposures were greatly benefited. In his cases, after four to six exposures, the scales fell off with no bleeding. In two cases some excoriation appeared on the exposed areas, disappearing in two weeks. Recurrences took place in all cases.

Sjögren and Sederholm § in two cases have found the use of *x*-rays of but slight value. In these cases there was slight improvement, which proved temporary.

* Deutsch. med. Wochens., 1900, xxvi, p. 546. † Lancet, 1901, ii, p. 144.
‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, v, p. 39.
§ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.

Williams* has reported one case: "A. B. Psoriasis of forty years' duration. When this patient came to me for treatment by the *x*-rays, nearly the whole of the front, back, and sides of the body were affected. Five exposures of twenty minutes each caused marked improvement in the area treated; the skin became soft and smooth, although still remaining of a reddish color for a few days."

Scholtz† states that in the treatment of psoriasis there is great improvement under *x*-rays. In most patients almost complete healing has resulted; in some absolute cure. Where the disease is not entirely removed, the subsequent application of chrysarobin quickly completes the cure. After three or four exposures of fifteen to twenty minutes, at 40 cm. distance, the intense red color is lessened and a yellowish-brown pigmentation begins on the edges of the affected areas. The scales form less rapidly and may be detached without the appearance of the characteristic bleeding points. Later the pigmentation spreads and becomes more intense and of a copper brown color. Finally the scales fall off and the skin appears smooth with merely slight roughness and pigmentation both over the diseased area and over the normal skin. These changes have taken place in several of his cases.

I have treated patches of psoriasis on the forearms in a patient with a very severe intractable psoriasis of many years' duration.

Case 31.—In this case, without at any time getting up a reaction, it has been possible to improve the condition very much. The scales fall off, the redness becomes markedly less, and the skin almost smooth, but the disease has shown a tendency to recur.

There is no doubt that patches of psoriasis can be cleared up by exposure to *x*-rays. There is no reason to believe, however, that such treatment will overcome the marked tendency of the disease to recur, and, as experience already shows, relapses will probably usually occur. The method, however, has the advantage of being free from the use of the unsightly

* "The Röntgen Rays in Medicine and Surgery," p. 653.

† Arch. f. Derm. u. Syph., 1902, lix, p. 421.

and disagreeable local applications used ordinarily in treating psoriasis and is easy of application. In addition, it is effective in certain intractable cases in which the ordinary remedies have failed.

In carrying out the treatment in psoriasis, where the disease is at all extensive, it is desirable, as Hahn suggests, to place the tube at some distance from the surface, in order that an almost equal effect of the rays may be produced at one time over a large surface.

Lichen Planus.—Scholtz * has reported the only case in the literature of lichen planus treated by *x*-rays—a patient with universal lichen planus in which the eruption on the right leg disappeared after a few exposures with slight scaling and pigmentation. At the same time there was noticeable increase in other parts of the eruption which were unexposed. Scholtz concludes that in lichen planus cure by *x*-rays is not so quick as by other means, but a trial of the method is strongly to be advised in obstinate cases.

Case 32.—I have treated by *x*-rays one case of lichen planus of the scrotum. This patient, a man twenty-nine years old, in good health, had an indurated, sharply defined, irregular patch of lichen planus on the scrotum 2½ by 4 inches in size. There were also two or three other small patches one-half inch in diameter. The disease appeared three years after a severe nervous strain and had at no time shown any tendency to get well. There was no lichen planus elsewhere on the patient's body, but from the purplish color of the patches, the slight branny desquamation, the sharp border, the induration, the itching, and the character of the peripheral lesions, I have no doubt as to the diagnosis. This patient had thirty-one weak exposures between May 15 and July 18, 1902. The first effect was a relief of the itching, and soon the patches began to fade out. Since June 15, 1902, all trace of the disease has disappeared and the skin has been normal. There was no visible reaction produced in getting this improvement. With the exception of a group of lesions ¼ inch in diameter which appeared in July and quickly disappeared under *x*-ray exposures, there

* Arch. f. Derm. u. Syph., 1902, lix, p. 421.

has been no evidence of the disease since June, 1902. It is hard to imagine the fading of a chronic inflammatory process in the skin in a way more striking than occurred in this case.

Lupus Erythematosus.—In consequence of the good effect of *x*-rays in lupus vulgaris their use was tried in lupus erythematosus early in the history of radiotherapy, and numerous reports upon the treatment of this disease by *x*-rays are found in the literature.

Beck * has reported one case of lupus erythematosus cured under *x*-ray exposures, and Lee † has reported one in which there was great improvement.

Sjögren ‡ has treated six cases of lupus erythematosus, of which five have been cured. All, however, required repeated periods of treatment on account of recurrences, which were probably due, in his opinion, to some areas not having been properly submitted to the rays. He found that treatment must be carried to the point of severe reaction. A clear atrophic skin is seen after a cure of the patches, similar to very thin scar tissue.

Startin § has reported the case of a young married woman with a well-marked butterfly patch of lupus erythematosus, bright red in color and acutely inflamed. Other treatment having proved ineffective, the case was given *x*-ray exposures every three days until six treatments had been given, the result being the formation of a healthy looking cicatrix.

Jutassy ‖ has reported the cure of a case which remained well eighteen months, when there was a slight recurrence.

Schiff and Freund ** have reported the cure of a case of lupus erythematosus of the side of the face, in which there was the unintentional production of an alopecia that proved permanent. This they very reasonably attribute to the effect of the disease rather than to the *x*-rays. In another case of Schiff's †† a patch of lupus erythematosus on one side of the

* Medical Record, 1902, lxi, p. 33.

† Brooklyn Med. Jour., 1902, xvi, p. 85.

‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, v, p. 37.

§ Lancet, 1901, ii, p. 144.

‖ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1900, iii, p. 119.

** Festschrift Neumann, p. 805. †† Wien. med. Presse, 1899, xl, p. 57.

face was cured by *x*-rays, while the condition of the patch on the other side, which was not exposed, was not affected. The skin after the disappearance of the disease was entirely smooth, and even almost normal in appearance.

Török and Schein* have reported two cases with improvement. Scholtz† states that in lupus erythematosus he has obtained by severe exposures followed by superficial necrosis results very satisfactory from a cosmetic point of view, but in the course of a few months relapses have occurred. In other cases apparently complete cure has resulted from slight exposures continued for months. Sjögren and Sederholm‡ and Grouven§ are of similar opinions.

On the other side, Hall-Edwards‖ has reported a case of lupus erythematosus of the face and arm in a girl eighteen years old, in which the patch on the arm was given one exposure at one inch, and a second nine days later. An *x*-ray slough resulted with an ulceration which healed in two months. The unexposed disease on the face disappeared sooner.

Case 33.—I have had under treatment for four months one case of lupus erythematosus—a typical saddle-shaped patch on the nose and cheeks, in a woman thirty years old. The disease has existed for eight years and has had previous *x*-ray exposures which were carried to the point of producing an acute dermatitis without effect on the disease. Under *x*-ray exposures which have not been sufficiently intense to cause an acute reaction there has been very marked improvement in the disease. It has gotten better than it has been in many years before. The skin is smooth, without elevation or scaling, but there is still some induration at certain points of the border, so that the disease is not yet cured.

With a disease so capricious in its course as lupus erythematosus one must be extremely careful in drawing any conclusions as to the efficacy of any method of treatment, and it is impossible with our short experience with *x*-rays in this disease to form

* Wien. med. Wochens., 1902, lii, p. 847.

† Arch. f. Derm. u. Syph., 1902, lix, p. 421.

‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145

§ Deut. med. Wochens., 1901, xxvii, V. B., p. 119.

‖ Edinburgh Med. Jour., 1900, xlix, p. 139.

a definite opinion as to their value. It seems probable, however, from our present experience that *x*-rays will prove an addition to the measures at our command in the treatment of lupus erythematosus. Certainly the reports which we have show better and more constant results than are gotten by any other method of treating this extremely capricious disease. It is probable that some cases will not be affected by them, and surely relapses in a certain proportion of the cases must be expected. But even granting this, there is still a chance of the method proving an advance in treatment. Bearing in mind other methods of treating lupus erythematosus and our experience in the treatment with *x*-rays of other chronic inflammatory processes in the skin, it seems probable that the method of using *x*-rays in the treatment of lupus erythematosus that will be most efficient is the use of exposures of weak intensity, which may be kept below the point of causing an acute reaction. In my opinion these mild exposures should be tried first, and intense exposures resorted to only when the weaker ones have persistently failed.

Prurigo and Urticaria Pigmentosa.—It is interesting to note, in connection with the consideration of the foregoing diseases, reports upon the treatment with *x*-rays of prurigo and urticaria pigmentosa.

Hahn * reports the cure of a case of prurigo, without the induction of any reaction. The formation of nodules and the itching ceased altogether except in those places not directly reached by the *x*-rays. On the other hand, Scholtz † reports that in a case of prurigo treated by *x*-ray exposures, no effect was seen.

Török and Schein ‡ have reported the successful treatment of urticaria pigmentosa which was exposed to *x*-rays with the production of an acute dermatitis. With the subsidence of this reaction the skin over the whole area became darkly pigmented and the urticarial markings disappeared, and could not be made to reappear by mechanical irritation. The pigmentation finally almost entirely disappeared.

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, v, p. 39.

† Archiv f. Derm. u. Syph., 1902, lix, p. 121.

‡ Wien. med. Wochens., 1902, lii, p. 847.

CHAPTER X.

TREATMENT OF TUBERCULOSIS BY X-RAYS.

Lupus Vulgaris.—The treatment of lupus vulgaris by exposure to *x*-rays was the first use of that agent that was made in the treatment of cutaneous disease. It had previously been used by Freund in the removal of hair, but its first application to diseased tissues was in lupus vulgaris, and the first intimation that we had of its brilliant therapeutic possibilities was shown in its effect in removing the lesions of lupus. It is an interesting fact that the first successful use of radiotherapy was in the same disease in which Finsen had had such notable success by the use of phototherapy, and it may be that among the debts that we owe to Finsen is to be included the fact that his demonstration of the value of light as a therapeutic agent in skin diseases was a factor in suggesting the application of *x*-rays in similar conditions.

The use of *x*-rays in lupus is, I think it may be safely said, an established method of treatment. Many writers have given testimony as to the success of the method in lupus. Among those who have done valuable work in this field may be mentioned especially Schiff and Freund,* Gassmann and Schenkel,† Hahn and Albers-Schönberg,‡ Kümmel,§ in Germany and Austria; Scholefield,‖ Holland,** Hall-Edwards,†† and Startin,‡‡ in England; Jones,§§ Knox,‖‖ and Greenleaf,*** in the

* Wien. med. Wochens., 1898, xlviii, p. 1058.
† Fortschr. a. d. Geb. d. Röntgenstrahlen, 1899, ii, p. 121
‡ Münch. med. Wochens., 1900, xlvii, pp. 284, 324, 363.
§ Arch. f. klin. Chir., 1898, lvii, p. 630.
‖ Brit. Med. Jour., 1900, i, p. 1083.
** Liverpool Med.-Chir. Jour., 1899, xix, p. 10.
†† Edinburgh Med. Jour., 1900, xlix, p. 139.
‡‡ Lancet, 1901, ii, p. 144. §§ Phila. Med. Jour., 1900, v, p. 63.
‖‖ Jour. Am. Med. Assoc., 1900, xxxv, p. 1210.
*** Buffalo Med. Jour., 1901, xli, p. 189.

United States. The first report of the successful treatment of lupus vulgaris by *x*-rays in the United States was the very valuable report of P. M. Jones, of California, January, 1900, which antedated by ten months any other scientific report upon this subject in the United States. The second case reported was that of Knox, in November, 1900. The third case was Case 34 in my series, which was reported one month later. The testimony as to the value of *x*-rays in lupus vulgaris is conclusive, and so well established that it will hardly be necessary to go into the detailed consideration of the cases reported.

My own cases are typical of the results which have been obtained in lupus. I have treated four successive cases of lupus vulgaris, in which sufficient time has passed to allow an opinion to be formed as to the permanency of the results.

Case 34.—Mrs. ———, aged thirty-eight, was referred to me May 8, 1900, by Prof. H. B. Favill, of Rush Medical College, with a diagnosis of lupus for treatment with Röntgen rays. The condition at that time is shown in the accompanying photograph (Fig. 106). The extent of the disease on the left side of the face and the neck is indicated in the photograph. It also extended over on the right side of the chin and up on the right cheek beyond the angle of the mouth. This entire area was covered with lupous ulcers and unhealthy scars. The ulcers were the typical flabby, soft, indolent ulcers of lupus covered with reddish-brown crusts. The scars were thick, red, band-like, and very disfiguring, and were most marked under the chin ; they were sufficiently rigid materially to interfere with motion. At many points in the scars there were recurrent ulcers. Typical "apple jelly" tubercles of lupus were easily demonstrable in any part of the diseased area. The point of greatest activity of the lupus was an area with a diameter of perhaps two inches around the left angle of the mouth. The ulcers involved the mucous membrane of the lips at this point, but no lesions were found within the buccal cavity. There was no evidence of tubercular involvement of the deeper structures. There were no deep sinuses and no tubercular glands. The case was, in short, a lupus and not a scrofuloderma.

Fig. 106.—Lupus.

Fig. 107.—Condition after three weeks' treatment.

Fig. 108.

The disease began, the patient thinks, about four years ago in an innocent-looking ulcer the size of a pea on the neck, and gradually spread from that point. The disease, however, was so benign in appearance that little attention was given it and no physician saw it. It is probable that it had existed some time before it attracted notice. The case had had no treatment before I saw it except the application of salves, which had had no influence on its course. It had steadily progressed from bad to worse, ulcers healing at times or new ones appearing, but more tissue constantly becoming affected. At the time the patient appeared for treatment her general condition was considerably run down, but without evidence of other disease than the lupus. There was no indication of tubercular involvement of the lungs. She had had the usual diseases of childhood, but had had no serious illness except an attack of appendicitis about five years ago. She has never, within her memory, had an eruption except the lupus. As a young baby she is said to have had an eruption of short duration after vaccination, which was probably an impetigo. Her father died at sixty-nine, of bladder trouble. Her mother is living, aged sixty, but has been blind for thirty years and has always been "scrofulous." She has a brother aged twenty-six and a sister aged thirty-two, both in good health. A brother aged twenty-three has a chronic cough. Several brothers and sisters died in childhood.

As to the diagnosis, the presence of the pathognomonic tubercles, the indolent ulcers with soft reddish borders, the thick band-like scars showing recurrent tubercles and ulcers, the slow course and painless character of the disease, are all characteristic of lupus and serve to differentiate it from syphilis or carcinoma. That the disease was not blastomycetic dermatitis, which sometimes so closely resembles lupus clinically, was shown by the absence of blastomycetes. I have sections made from a piece of tissue taken from the border of an active ulcer. These sections show the structure of tuberculous tissue. Tubercle bacilli were found in this tissue by me, and independently in other sections by Dr. Roehr, of the Columbus Laboratory. I was fortunate in having the case seen by Dr. H. G. Anthony,

professor of dermatology in the Chicago Polyclinic, when it first came to me; he agreed in the diagnosis of lupus.

Treatment by exposure to *x*-rays was begun on May 8, 1900, and was continued daily, except Sundays, until May 26. By May 24 many of the lesions were clearing up and beginning to heal. May 26 the exposed surfaces showed some reaction from the effects of the rays; the lupous tubercles were brighter in appearance and the borders of the ulcers redder and swollen. The changed appearance at that time is indicated in figure 107. Treatment was discontinued until June 4, by which time the reaction had almost disappeared. The treatment was continued from June 4 until June 21 daily as before, when considerable dermatitis developed. This dermatitis was confined to the diseased tissue and did not involve the surrounding healthy skin which had been exposed to the rays. At this time the ulcers were healing rapidly. The treatment was discontinued until July 2, when reaction had entirely disappeared and almost all of the ulcers were healed. From July 2 till August 10 the treatments were continued, not daily, but with a few intermissions of three or four days as the condition of the face indicated. During this time there was gradual improvement in the condition, the remaining ulcers healing, tubercles being absorbed, and the entire surface becoming covered with healthy scars.

By the latter part of July the left side of the face showed few traces of the disease. The diseased area on the right side, however, which from the manner of making exposures had received less of the effects of the rays than the left, still showed lupous nodules and open ulcers. Accordingly, additional exposures were begun directly over this area on July 30 and continued daily in a maximum amount until August 10. Under these extra exposures the lesions immediately began to improve, and by August 10 had entirely healed. This observation, which is but confirmatory of similar observations made by Schiff and by Jones, leaves little room for doubt as to the positive effect of the rays.

On August 10 treatment was discontinued, because of my going away. At that time the only evidence of lupus that I

could find was at the angle of the mouth, where there was still a focus of disease. On September 13 the patient returned; there was then no evidence of disease at any point except at the angle of the mouth where the tubercles persisted. Treatment was resumed with exposures over the left angle of the mouth. September 20 the tubercles on the upper lip were breaking down and an elliptical ulcer the size of a little finger-nail had developed, which within the next few days began to heal. On October 2 some erythema over the exposed area had developed and treatment was given up until October 8. By October 8 the last lesion had disappeared. From October 8 to November 8 the patient had daily exposures on the left side of the chin and on the neck under the chin. These exposures were continued for two reasons: (1) the old keloid-like scars had shown under the exposures great improvement in flexibility, softness, and color, and it was desired to carry this effect as far as possible; (2) to destroy any concealed lesions still present. Since October 8, 1900, no evidence of disease has been demonstrable. The results of the treatment are indicated in a photograph (Fig. 108) taken November 10, 1901. There remained no evidences of the disease except the scars.

Attention is called to the character of the scars. The only thick ones left are those which were in existence before the treatment began, and they have become less prominent, much softer, and more pliable. The scars which have taken the place of the ulcers present when treatment began are soft, thin, flexible, and white, and are as healthy looking as they could possibly be. At the beginning the scars on the neck interfered very considerably with motion; now they interfere scarcely at all. The last exposure given this patient was January 12, 1901, and she remains well at the present time, twenty-three months later.

Case 35.—Girl, aged eighteen, referred to me by Prof. A. J. Ochsner of the University of Illinois with a diagnosis of lupus, for treatment with *x*-rays. This was a typical lupus of the nose, involving tip, alæ, and septum. The disease began four years ago on the tip of the nose and gradually spread in spite of persistent treatment. The patient had been under Dr. Ochsner's

treatment for two and a half months, and during this time the condition had greatly improved. The photograph (Fig. 109) shows very well the condition at the time she came under my care. The entire tip of the nose and alæ were a mass of reddish-brown, soft, friable, apple-jelly, lupous tissue. The middle half was ulcerating and scarred. The disease had also involved the mucous membrane of the nasal orifices.

Exposures were begun on October 1, 1900, and were given almost daily until December 20.

With the exception of a reddening, sharply confined to the lupous area, which occurred after thirty sittings, there was no change in the condition until the middle of December, when considerable redness developed in the lupous tissue and slight redness in the surrounding healthy part which had been exposed. As the lesions had proved quite intractable, exposures were continued until ten more were given. On December 20, after sixty-four exposures, treatment was stopped on account of dermatitis and tenderness of the exposed surfaces; on December 28, without further exposures, a not very tense bulla, the size of a thumb-nail, developed on the tip of the nose, where the effect of the light had been greatest. This was accompanied by tenderness and slight pain. Within a week most of the dermatitis subsided, the bulla ruptured, and at its site there showed a very superficial ulceration. This bled easily, was quite painless after a few days, and was covered with a superficial necrotic membrane. Its borders rapidly contracted, and on January 20 it had entirely healed. With the healing of this surface almost all traces of lupus disappeared. There was left only a suspicious area, the size of a little finger-nail, on the right ala; to remove this, exposures were given, at from one to two days' interval, during February and March. After thirty sittings this spot on the ala of the nose became red and swollen, and these manifestations were quickly followed by a very remarkable softening of the lesion, so that it felt as soft as a flaccid bulla, without, however, any suspicion of a separation of the epidermis occurring. The redness and softening were quickly followed by the disappearance of the last suspicious area. From the beginning of treatment up to the time of the disappearance of the

Fig. 109.—Lupus.

Fig. 110.

last lesion, March 16, 1901, she had ninety-five sittings, extending over a period of six months. For two months after the disappearance of the last lesion she has had irregular exposures as a precaution. The result of treatment is shown in the photograph (Fig. 110). She has had no treatment since May 1, 1901, and there has been no recurrence.

The result from a cosmetic standpoint is, I believe, as perfect as can possibly be expected. There is some diminution in the size of the nose, but aside from this there is no deformity. There is entire absence of scarring in all of the areas treated by this method ; the only scars are those on the upper lip resulting from ulcers which healed before this treatment was begun. The skin is soft, pliable, and natural in appearance.

Case 36.—Lupus hypertrophicus. Mrs. ———, aged thirty-eight, fifteen years married, was referred to me in March, 1901, by Dr. A. E. Matthaei. She had never had a serious illness except vesical calculus and cystitis seven years ago, which were relieved by operation, and had never had any sort of skin eruption, except the one on her chin. Her history gave no suspicion of syphilis. She had four healthy children living and had had one miscarriage of a healthy fetus between the third and fourth months. Her family history was without significance, except that her father died at the age of forty-nine of chronic lung trouble. The patient was sparely built, and not very vigorous looking, but there was no organic disease.

When she came to me, in March, 1901, there were two hypertrophic patches, one on the tip of the chin, the other under the chin, as shown in figure 111. These consisted of closely set groups of waxy, glistening, almost translucent tubercles which at a distance looked very like patches of zoster. The first patch to develop, the one under the chin, appeared about seven years ago as a pinhead-sized lesion, around which other lesions gradually developed. This patch was cut out, but the disease recurred in the scar, and two years later the group of lesions appeared on the tip of the chin. Since that time the disease has persisted in spite of treatment and gradually increased to the condition shown in figure 111. The scar in the center of the patch under the chin, resulting from the previous opera-

tions, produced a similarity in appearance to syphilis which was confusing.

The case was first shown by me in March, 1901, at a meeting of the Chicago Dermatological Society, as a case of hypertrophic lupus. There was then a difference of opinion between hypertrophic lupus and tubercular syphilide. The case was afterward shown at a meeting of the American Dermatological Association, where most of the members, I believe, agreed in the diagnosis of hypertrophic lupus. The microscopic findings were not conclusive, and in order to exclude syphilis, the case was for two and a half months put under full doses of iodides and mercury and mercurial ointment locally. This treatment had no effect.

After the failure of mixed treatment, the case was put under daily *x*-ray exposures in June, 1901. The effect was not prompt, but after two months considerable erythema was produced which was accompanied by marked shrinkage of the lesions. The exposures were continued until August 26, with the production of an acute dermatitis, and by this time the tubercles had shrunken until the surface was flat. The dermatitis was, curiously enough, confined sharply to the diseased area.

The patient has been well since September, 1901, but had prophylactic exposures at intervals until March, 1902. There is no scarring on the tip of the chin and very little under the chin (Fig. 112).

Case 37.—Trained nurse, aged forty-one, with a very severe lupus vulgaris of at least twenty-five years' duration. She had been persistently treated, and in October, 1898, the diseased area was removed and a plastic operation done for the restoration of the nose and of the central part of the face. The disease recurred in the scar and has since involved the nose and all of the surrounding skin. The nose has been almost entirely destroyed since the recurrence. This case was under treatment more or less continuously from November, 1900, until April, 1902, and during this time the disease not only did not spread, but the area involved was considerably diminished. At no time, however, did the improvement approximate a cure. In April, 1902, she was unavoidably compelled to discontinue

Fig. 111.—Lupus hypertrophicus.

Fig. 112.

treatment, and since that time she writes me she has grown very much worse. This case must be regarded as a failure. The part of the face restored by the plastic operation was extremely susceptible to *x*-rays and the healthy tissue seemed unable to cope with the lupous foci in the way in which it has done in the other cases. The result in this case is similar to results with ultra-violet rays reported by Finsen in cases where the disease has recurred after plastic operation.

Case 38.—Woman, aged thirty-five, with lupus vulgaris of twenty years' duration. At the time of coming under treatment there was lupus of the cheeks and nose, of the back of the right hand, and the back of the right elbow. The area on the face consisted of old scar tissue, filled with apple-jelly tubercles, but without ulceration. While the disease had existed for a long time, there had been a comparatively small amount of destruction of tissue. There was an ulcerating area of lupus almost covering the back of the right hand. There was a similar ulcerating lupous lesion, 1½ by 2½ inches, on the back of the elbow. Between May 19 and September 11 the patient had 48 exposures over the face with the production of slight dermatitis on two occasions. The face had gradually improved during the treatment, until on December 1 the change is very marked. The redness has entirely disappeared and the scars are white and soft, but there still remain numerous pale tubercles in the skin representing previous typical apple-jelly tubercles, so that it cannot be said that the face is free from disease. The back of the right elbow was given fifteen exposures during August and September with the development of a rather acute dermatitis, on the subsidence of which the disease entirely disappeared and left a healthy scar. At the same time the back of the right hand was given fifteen exposures, which resulted in an acute weeping dermatitis. Since the disappearance of this the hand also has been free from evidence of lupus. At the present time, December 1, the hand and elbow may be said to be symptomatically cured, and while the same cannot be said of the face, which has been treated less vigorously, the improvement is so great that there seems every reason to believe that a successful result will be attained there also.

The results in Cases 34, 35, and 36 are as good as can possibly be hoped for by any method. There has been no destruction of healthy tissue in getting rid of the disease, and less scarring could not possibly remain after any lesions as extensive as these were. The scars are white, soft, and pliable, and indeed in Cases 35 and 36 are hardly to be called scars at all. As to the permanency of the results, Case 34 has been well twenty-seven months, Case 35 twenty-one months, and Case 36 fifteen months.

As said before, these cases are typical of the results that have been obtained by other workers, and they can leave no doubt of the value of this method of treatment of lupus. No other method of treating lupus has ever shown anything like as good results except Finsen's method with ultra-violet light. Between the results obtained by these two methods there is, I am convinced, no room for choice. Both give excellent results, both show scarring of exactly the same character, and there is no reason to believe that either has any advantage over the other as regards the permanency of the results. Perhaps radiotherapy is a quicker method of curing these cases than phototherapy, but with the improved lamps now in use the length of time required for treatment by Finsen's method has been much reduced, so that it approximates the time required for treating these cases by *x*-rays.

The length of time required in treating these cases probably varies considerably according to the vigor with which the treatment is carried out. Cases are reported in which a few strong treatments scattered over several weeks have proved sufficient. In my cases the length of treatment before the disease disappeared in Case 34 was five months; in Case 35, five months; in Case 36, four months. It is doubtful if anything is gained by trying to shorten the time of treatment and treating these patients so vigorously as to produce a marked reaction in the skin. The logical course to pursue is to get up a sufficient reaction to cause degeneration of the diseased tissue without destructive effect upon the healthy stroma. In Case 34 in my series it was found unnecessary to cause more than the faintest erythema. In Case 35 most of the disease

disappeared without the production of more than a moderate dry dermatitis, but to get rid of the last lesion it was found necessary to carry the reaction to the point of producing a bulla. In Case 36 the reaction was carried to the point of producing an acute dermatitis on several occasions.

Upon this point Scholtz * has observed that "neither that method of treatment which avoids any inflammatory reaction, nor that in which a severe reaction is produced, can be said to be the best for all cases of lupus; nowhere is the personal application of treatment a more necessary consideration than with *x*-rays. Our observations have shown that energetic treatment leading to superficial excoriation and necrosis is more effective than slight exposure. The process of healing—molecular destruction of the tubercles, reactive inflammation, replacement of the lupous tissue by new connective tissue—is much the same whether exposures be severe or slight. But in the former case the reaction is more active and the process penetrates more deeply. Choice between these two methods must depend on the severity of the lupus, on its locality, and on the convenience of the patient." He further adds that in very superficial cases they sought to avoid serious *x*-ray dermatitis, producing only a slight redness. The greater number of their cases, however, were severe, and in these they produced superficial necrosis through intense exposures. In such cases they found that the sores produced caused very little pain, were easily handled, healed in a few weeks, and their scars were soft and smooth, and the cosmetic result not appreciably worse than when the treatment was less vigorously carried out. They always undertook to avoid deep necrosis, but their experience led them to believe that there was no reason to beware of a superficial necrosis. In my cases I have never found it necessary to carry the reaction to the point of producing even a superficial necrosis, and I see nothing that would be attained by such reaction that could not as well be attained by the simple production of an acute weeping dermatitis. I believe the best method of procedure in all these cases is first to see if the results cannot be obtained by producing a moderate reaction, and only after

* Arch. f. Derm. u. Syph., 1902, lix, p. 421.

this fails to resort to radical exposures. It certainly is not necessary in most cases to cause ulceration of the lupous tubercles in order to get rid of them.

Schiff and Freund * called attention to the shrinking without ulceration of the lupous tubercles, and this observation has been confirmed by numerous writers. In none of my cases have I seen a lesion disappear by ulceration. They shrink, lose their color, and disappear, leaving a healthy looking scar, or no scar, without breaking down.

There is universal testimony as to the cosmetic excellence of the scars from this method of treating lupus, just as from the treatment by Finsen's method. The scars are soft, white, and pliable, and show none of the keloid-like character that we have been accustomed to see in lupous scars heretofore. Moreover, the scars left by lupus which has disappeared spontaneously or under other methods of treatment have in many cases been found to show marked improvement after exposure to *x*-rays. This is well illustrated in the very great improvement in the pliability and thickness of the scars of the neck in Case 34 of my series.

In my cases the only other treatment that the patients have had has been surgical cleanliness. This is in accord with the reports of most other observers, who have agreed that the *x*-rays have proved sufficient without the aid of other local treatment. When one remembers how trying the usual methods of treatment are, the fact that their aid is not necessary does not appear as the least of the advantages of the treatment of lupus by radiotherapy.

Tuberculous Ulcers and Scrofuloderma.—In tuberculous ulcers and in scrofuloderma, using that term to describe the diseased conditions of the skin and subcutaneous tissues that are associated with tubercular glands and other deep-seated foci of tuberculosis, there are good grounds for the use of *x*-rays, but as yet the literature contains little upon the subject.

Lortet and Genoud † have reported their findings in eight guinea-pigs inoculated in the inguinal region with tuberculosis.

* Wien. klin. Wochens., 1900, xiii, p. 827.

† Semaine méd., 1896, xvi, p. 266.

Of these, three that had *x*-ray exposures after inoculation did not develop tuberculosis, while in the five other pigs, which were not exposed to *x*-rays, tuberculous ulcers developed at the points of inoculation.

Mühsam * concluded, so long ago as 1898, from experiments on guinea-pigs, that *x*-rays, while exercising no influence on general tuberculosis, restrained local tuberculosis to a point where its action was very slight.

Williams † has reported a case of tuberculosis of the dorsal surface of the foot treated by *x*-rays, in which there was a microscopic diagnosis of tuberculosis. The lesion involved the dorsum of the fourth and fifth toes and the contiguous surface. Under ten exposures to *x*-rays, varying from five to fifteen minutes in length, the pain entirely ceased and the growth in great part disappeared.

Bagge ‡ has reported an extensive ulcerating tuberculous lesion extending from the front of a man's chest around under the axilla to the back, which had developed from a burn infected by tuberculosis and had remained unhealed for seventeen years. The area was treated by *x*-ray exposures, and in three weeks the entire surface healed.

Case 39.—I have treated one ulcer of the leg, probably tuberculous. Mrs. ——, aged twenty-five, referred to me by Dr. William Cuthbertson, of Chicago, with a tuberculous ulcer on the back of the middle third of the leg, four inches in vertical diameter and two in transverse, and quite deep. This ulcer had persisted for ten months in spite of most vigorous treatment. The patient was run down physically, but had no evidence of tuberculosis elsewhere. She was put under *x*-ray exposures August, 1901, and these were continued daily for two months, and after that irregularly until December 23, 1901. At the end of two weeks the lesion began to clear up and show healthy granulations. In two weeks more it was reduced to one-half its previous size, and by November 1, 1901, was entirely healed with a healthy looking scar. During this time the

* Deut. med. Wochens., 1898, xxiv, p. 715.

† "The Röntgen Rays in Medicine and Surgery," p. 662.

‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1899, iii, p. 218.

patient was on crutches, but used the leg slightly. In March, 1902, the disease recurred in the scar, and at the present time is, I believe, as extensive as it ever was, although she has been having some *x*-ray exposures.

Sjögren and Sederholm * have reported, under the title of tuberculides or scrofuloderma, five cases which have shown improvement without entire cure under *x*-ray exposures. These cases, however, are not the cases usually classed under scrofuloderma, but are cases showing cyanotic nodular lesions on the extremities in scrofulous subjects, and are usually embraced under the title scrofulides or tuberculides. They are hardly entitled to weight in considering the effect of *x*-rays on tuberculosis of the skin, until we know more of their essential character than is known at present.

Williams † refers to two cases of tuberculous sinuses of the neck, of which Dr. F. M. Briggs has given him a personal report, that have been greatly benefited by treatment with *x*-rays. One case, a boy fourteen years old, had a long-standing suppurating adenitis of the cervical glands, which had resisted operative treatment for eight months. There was one sinus opening on both sides of the neck. The case was put under *x*-ray treatment, and after six exposures the opening on one side had closed, and there was only a small amount of discharge from that on the other side. At the time of report the patient was still under treatment.

The second case was that of a boy eight years old who had a freely discharging sinus on one side of the neck of nineteen months' duration in spite of constant treatment. After two *x*-ray exposures the sinus stopped discharging, and it had not reopened at the time of the report.

Case 40.—I have treated one case of scrofuloderma with cervical adenitis, referred to me by Prof. A. J. Ochsner, of the University of Illinois. This patient, a girl twenty-four years old, had had several operations for tuberculous glands on either side of the neck and in either axilla. The last operation was November 5, 1901, when a mass of tuberculous glands

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.

† "The Röntgen Rays in Medicine and Surgery," p. 664.

was removed from the right axilla and a small fluctuating mass from the neck below the right mastoid process. The wound in the neck refused to heal, and on November 21, 1901, when she was referred to me for *x*-ray treatment, there was a deep sinus on the right side of the neck and the tissues presented the usual appearance of scrofuloderma. The scar tissue on both sides of the neck was unhealthy looking, dense and inelastic, and there were several suspicious indurated masses on either side. From November, 1901, to March, 1902, she had 30 exposures, when the sinus healed and the scar tissue in every way took on a much more satisfactory appearance. Since that time she has had exposures at average intervals of a week and the improvement has remained. It is not possible to say that the case is entirely cured, but there are no sinuses or evidences of adenitis, the scar tissue in the neck is healthy looking, and much softer and more pliable than at the beginning of treatment. In view of the previous history of the case and its condition at the time of the beginning of treatment there can be little doubt of the marked benefit derived from the treatment. The patient still has exposures once a week.

Tuberculous Vesical Fistula.—I have treated one vesical fistula opening upon the right buttock, resulting from tuberculosis of the deep urethra and bladder, in a man aged forty, referred to me by Dr. T. A. Davis, of the University of Illinois. This patient had sixty *x*-ray exposures between April 25 and August 1, 1902. The reaction was carried to the point of producing pigmentation and slight dermatitis on several occasions. The induration, which was quite marked about the fistula at the beginning of treatment, became unquestionably very much less, but aside from that there was little improvement and the patient discontinued treatment.

Tuberculous Glands.—There is reason to think that a very general attempt is being made at the treatment of tuberculous cervical adenitis by *x*-rays, but there is as yet little literature upon the subject.

Williams * states that enlarged cervical glands, even when

* "The Röntgen Rays in Medicine and Surgery," p. 674.

of great size, respond surprisingly well to treatment by *x*-rays, but reports no cases.

In a personal communication to the writer Dr. H. A. Brennecke, of Aurora, Ill., has reported the entire disappearance of a very large mass of cervical glands in the neck of a girl fifteen years old, whom I saw with him before the beginning of treatment.

In addition to Case 40, referred to above, under scrofuloderma treated by me, I have treated the following cases of tuberculous glands of the neck:

Case 41.—Miss ———, aged seventeen, with tuberculous family history. One tuberculous gland was removed June, 1901. At the time she came to me for treatment there was a gland the size of a filbert on the left side of the neck two inches above the clavicle. On the right side there was a group of painless glands five or six in number, the smallest the size of a split pea, the largest the size of a filbert. Between February 15 and March 28, 1902, she received twenty exposures over these glands on either side, with the production at one time of an acute dermatitis. In this time there was certainly decided diminution in the size of the glands, but the patient was careless of treatment and discontinued it without relief.

Case 42.—Man, aged twenty-five, who two years before had an operation for the removal of tuberculous glands on the right side of the neck. At the time of coming for treatment, June, 1902, there was a gland the size of an olive at the upper border on the sternocleidomastoid muscle. After 15 exposures in two months dermatitis developed, since the subsidence of which exposures have been given at one period to the point of producing a dermatitis again, and since that time at intervals of a week. After the development of the first dermatitis the gland broke down and its contents were evacuated by an incision. Under subsequent exposures the cavity filled up with healthy granulations and a healthy scar formed. The case is still having occasional *x*-ray exposures.

Case 43.—Miss ———, aged thirty, with tuberculous glands of the neck, of several years' duration. At the time of coming to me for treatment there was a mass of non-fluctuating glands

on the right side of the neck as large as a fist; on the left side a number of glands as large as a filbert. The patient's general health has run down considerably during the past year, when the disease has been at its worst. At the time of coming under treatment she was fifteen pounds below her weight of a year before. This patient has been under *x*-ray exposures at intervals from June 19 to November 1, with the production of pigmentation and erythema on several occasions. During this time the glands have decreased decidedly and become much softer, and the circumference of the neck has decreased an inch, but on neither side have the glands as yet disappeared.

Case 44.—Girl, aged twenty, with tuberculous cervical adenitis of several years' duration. There was a dense hard mass of glands as large as a fist on the right side of the neck and a mass little smaller on the left side. Between May 27 and July 28, 1902, she had almost daily exposures on either side of the neck. Then erythema developed and exposures were discontinued for a month. Between September 2 and November 1 she had forty exposures. On several occasions a slight dermatitis has been produced which has promptly disappeared on rest. There has been distinct improvement in this case. The swelling of the neck has very nearly disappeared. The right side of the neck is of almost normal contour, but still shows a number of fairly hard nodules, the largest the size of a small filbert. The left side shows slight swelling just below the ear, due to a soft mass the size of an almond kernel.

Tuberculosis of Larynx.—The use of *x*-rays in tuberculosis of the larynx is also being tried quite extensively, there is reason to believe, but nothing definite upon the subject has as yet been reported. Ravillet * has reported benefit in one case of tuberculous laryngitis while under *x*-ray exposures.

Tuberculosis of Joints.—Leigh † has reported a case of tuberculosis of the elbow-joint which was considered to require operation but was exposed two or three times weekly for two hours to *x*-rays. After six exposures the inflammation disappeared completely and there has been no recurrence in eighteen months.

* Revue de la Tuberculose, April, 1897.

† American X-ray Jour., 1899, iv, p. 559.

Tuberculosis of Genito-urinary Tract.—The method deserves a trial in tuberculosis of the genito-urinary tract,—particularly in cases in which little is to be expected of surgery,—but there are as yet no reports in the literature upon this subject.

In all of these forms of tuberculosis,—tuberculous sinuses and ulcers, tuberculous adenitis, tuberculosis of larynx, and tuberculosis of joints,—there is enough ground for hoping for some benefit to justify a thorough trial of the method, since the cases are otherwise so difficult of relief. In tuberculous glands of the neck the method is in my opinion entitled to a very thorough trial before operation, particularly in view of the radical character of operations necessary in these cases and, even with such operations, the unsatisfactory character of the results. In tuberculosis of the larynx and of the joints the method offers sufficient grounds for expecting benefit to warrant its use as an auxiliary to other treatment.

Abdominal Tuberculosis.—Scholtz * and Mühsam † have concluded, independently, from experimental inoculation of tuberculosis in guinea-pigs, that *x*-rays have no effect on general tuberculosis.

On the other hand, Ausset and Bédart ‡ have reported two cases most interesting in this connection. First the case of a girl with chronic tuberculous peritonitis, with ascites and caseation, which was presented to the Société de Médecine du Nord in 1898. After unsuccessful attempts at treatment in various ways, including laparotomy, the patient was relieved by *x*-ray exposures, and has remained cured for eighteen months. They later presented the case of a girl four years old with chronic tuberculous peritonitis. Several members of the society concurred in the diagnosis. The case showed all the classical symptoms; circumference of the abdomen 64.5 cm., liver three fingers below the costal line. By exploratory puncture a gram of clear brown fluid was withdrawn. She was given *x*-ray sittings each second day for fifty-five days, at first for eight minutes, with the tube at 25 cm. from the abdomen, later for

* Arch. f. Derm. u. Syph., 1902, lix, p. 78.
† Deut. med. Wochens., 1898, xxiv, p. 715.
‡ Echo médicale du Nord, 1899, iii, p. 604.

fifteen minutes with the tube at 15 cm. On the twenty-first day the circumference of the abdomen began to diminish; on the fifty-fifth day it was 56 cm. and all liquid had disappeared. The sittings being interrupted for two months, the circumference increased to 59 cm. The sittings were then resumed for five weeks and the case dismissed with abdominal circumference 56 cm., no ascites, liver two fingers below the costal line, and weight increased from 16.5 k. to 19 k. The patient had absolutely no treatment other than *x*-ray exposures, and only her customary diet.

In personal communications to the writer, Professors Frank Billings and Henry B. Favill, of Rush Medical College, have reported their use of *x*-rays in conjunction with other treatment, including rest, in cases of tuberculous peritonitis; in these cases there has been marked improvement, but how much of it is attributable to the use of *x*-rays they think it is impossible to say.

Case 45.—I have used *x*-ray exposures in one case of chronic mesenteric tuberculosis of a not severe type, in a child eight years old, referred to me by Dr. L. L. McArthur, of Chicago. In this case the exposures were continued daily from May 7 to June 14, 1902. A very hard tube was used and the surface protected by an aluminum screen. Exposures were kept at a point which caused decided pigmentation of the skin without dermatitis. June 14 the exposures were discontinued and the child taken to the country. Four months after discontinuing treatment Dr. McArthur and Dr. Frank Billings reported that the masses were unquestionably diminished in size, but whether this is attributable to the summer outing or to the *x*-rays, or to both, it is impossible to say.

Pulmonary Tuberculosis.—Some attempt has been made at the treatment of pulmonary tuberculosis with *x*-rays, but without results that are convincing. Bergonié and Mongour, quoted by Dollinger,* state that in two cases of acute pulmonary tuberculosis in well-nourished individuals, reduced in strength by alcoholic excesses, no results were obtained by exposure to *x*-rays. In one case of slow pulmonary tuberculosis there was

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1898, ii, p. 70.

no effect. In a second case there occurred rapid improvement of the general condition without change in the local condition. In a third case there was local and general improvement for a month, when there was a severe attack of indigestion followed by aggravation of the disease.

Rudis-Jicinsky * has used *x*-rays as an adjuvant to other treatment of pulmonary tuberculosis, and reports that "from nineteen selected cases, in one year, one died from intestinal tuberculosis, four proved complete failures and the rest were doing comparatively well."

Reports of other cases of pulmonary tuberculosis treated by *x*-rays have been made by Gilman,† Burdick,‡ and Sinapius.§

On the other hand Havas ‖ has concluded, on what seems insufficient evidence, that *x*-ray exposures caused the assumption of virulence by a latent tuberculosis.

There is perhaps some ground for hoping for benefit from the use of *x*-rays as an auxiliary to other treatment in pulmonary and abdominal tuberculosis. It is not beyond reason that throwing *x*-rays day after day through the thorax or the abdomen might be of service in the treatment of tuberculosis of these parts. And since the treatment can be carried out without danger or inconvenience to the patient, and without interfering with approved methods of treatment, it would seem that the method is worthy of trial. It certainly does not hold out sufficient hopes of relief to warrant its use at the expense of residence in a bad climate, or abandonment of better tried measures. There is, in my opinion, no ground for believing that it is likely to increase the virulence of the process.

Syphilis.—Kümmell ** and Hahn and Albers-Schönberg †† have each reported one case of gummatous syphilide, mistaken for lupus, treated unsuccessfully by *x*-rays. In both cases the fact that no improvement occurred under *x*-ray exposures led to correct diagnosis.

* New York Med. Jour., 1901, lxxiii, p. 364. † Clinique, 1897, xviii, p. 360.
‡ Am. Electro-Therapeutic and X-ray Era, 1902, ii, No. 3, p. 1.
§ "The Röntgen Rays in Medicine and Surgery," p. 418.
‖ Arch. f. Derm. u. Syph., 1900, Festschrift Kaposi, p. 275.
** Arch. f. klin. Chir., 1898, lvii, p. 630.
†† Münch. med. Wochens., 1900, xlvii, 284, 324, 363.

I have exposed cases of ulcerating tubercular syphilides to *x*-rays while giving at the same time potassium iodide. All of the lesions, of course, rapidly cleaned up under the iodides, and I have not been able to see that the *x*-rays particularly influenced the result. Syphilitic ulcers can be cleaned up like any other infected ulcers by *x*-ray exposures, but not more quickly than they can be cleaned up by the usual wet dressings. Indolent, sluggish, syphilitic ulcers could doubtless be given the needed stimulation by exposing them to *x*-rays. Perhaps this could be better done in certain intractable cases by *x*-ray exposures than by the usual methods of stimulation; but further than this—and this is not an important rôle—it is doubtful if *x*-rays have any rôle to play in the treatment of gummatous syphilides. There is certainly no reason to substitute *x*-rays for the efficient method of treating these lesions that we already have.

Leprosy.—Sequeira * has reported a case of tubercular leprosy of the skin which has shown marked improvement under *x*-rays, the hard nodules softening and flattening down.

Allen † has been treating a case of leprosy with *x*-rays with perhaps some improvement.

Scholtz ‡ reports that in two cases of leprosy under treatment with *x*-rays no definite results have as yet been obtained.

Actinomycosis.—From the effect in similar conditions there is good reason to warrant the trial of *x*-rays in the treatment of actinomycosis, but there are no reports upon the subject in the literature.

Blastomycetic Dermatitis.—In a personal communication Montgomery has reported that he and Hyde have treated some cases of blastomycosis successfully by the use of *x*-rays locally, and moderate doses of potassium iodide internally. I have treated one case of probable blastomycosis, Case 142, page 532, by the use of *x*-rays and the internal administration of potassium iodide in ten-grain doses three times daily. This case

* Brit. Med. Jour., 1901, ii, p. 851.

† N. Y. State. Jour. of Med., 1902, ii, p. 176.

‡ Arch. f. Derm. u. Syph., 1902, lix, p. 421.

was a complete success, but the diagnosis is not conclusively established.

Case 45*a*.—I have under treatment at present one case of blastomycetic dermatitis involving the lower eyelid, which is a typical beginning case, and in which the diagnosis is fully established. Under small doses of potassium iodide three times daily, and with *x*-ray exposures to the point of producing an erythema, the disease has almost but not quite disappeared. There seems every reason to believe that a completely satisfactory result will be obtained. The patient has only had small doses of potassium iodide, ten grains three times daily, which is not sufficient to account for the very great improvement. The condition at the time of beginning treatment and the changes under treatment are shown in figures 113, 114, and 115.

Fig. 113.—Blastomycetic dermatitis.

Fig. 114.—Condition after one month's treatment.

Fig. 115.—Condition after two months' treatment.

CHAPTER XI.

CUTANEOUS CARCINOMA.

Carcinoma.—The most important and the most startling application which has been made of *x*-rays is their successful use in some malignant diseases. The first case * of malignant disease treated by *x*-rays was a cutaneous carcinoma—a rodent ulcer—which was treated by Stenbeck,† of Stockholm, and demonstrated on December 19, 1899. Several reports upon the use of *x*-rays in the treatment of carcinoma were published during the subsequent year, and the method began to attract attention. During the last eighteen months the use of the method in the treatment of malignant diseases has increased by leaps and bounds until now it is being given the widest trial. It is accordingly an extremely important matter to determine the extent and the limitations of use of *x*-rays not only in carcinoma but in other malignant diseases as well.

The number of recorded cases of carcinoma treated by *x*-rays is surprisingly large, and a review of them is of the highest interest. The number of my successive cases of carcinoma which have interest upon this subject and which I have to report is eighty-three.

Cutaneous Carcinoma or So-called Epithelioma.—Many writers have reported results in the treatment of epithelioma. Among these may be mentioned—in America, Johnson and Merrill,‡

* In the Bibliotheca medica, Abtheilung D II, Heft 8, 1900, Dr. Magnus Möller, in his article "Der Einfluss des Lichtes auf den Haut in gesundem und krankem Zustande," mentions a case of epithelioma treated by the *x*-rays by Sjögren. Stenbeck, in a note to his article, "Ein Fall von Hautkrebs geheilt durch Behandlung mit Röntgenstrahlen" (Mittheilungen aus den Grenzgebieten d. Med. u. Chir., 1900, vi, p. 147), states that this case of Sjögren's was exhibited at a meeting of the Swedish Medical Society, Dec. 19, 1899, not yet cured, at the same time that he (Stenbeck) demonstrated his case cured.

† Mittheilungen a. d. Grenzgeb. d. Med. u. Chir., 1900, vi, p. 347.

‡ Phila. Med. Jour., 1900, vi, p. 1089. American Medicine, 1902, iv, p. 217.

Williams,* Beck,† Rinehart,‡ Morton,§ Hett,‖ Hopkins,** Allen,†† Duncan;‡‡ in England, Taylor,§§ Ferguson,‖‖ Sequeira,*† Startin; *‡ in other parts of Europe, Stenbeck,*§ Sjögren and Sederholm,*‖ Scholtz.†*

One or more cases symptomatically cured have been reported by Beck †‡ one, Taylor †§ one, Ferguson †‖ one, Hett ‡* four, Rinehart‡† four, Third ‡§ two, Scholtz ‡‖ one, Morton §* one, C. W. Allen§† three, Sjögren and Sederholm §‡ four, Everett Smith §‖ one, S. Allen ‖* one, Pfahler ‖† three.

Williams has reported seven cases of epithelioma symptomatically cured and four in which there has been rapid improvement.

Sequeira has treated forty-five cases of epithelioma. According to his experience, the ulcers heal rapidly and cavities fill up in a remarkable manner. Difficulty has been experienced with hard raised edges, and slight and easily treated recurrences have been noticed. In the treatment of cancer by this method pain is relieved and the discharge dried up. In some cases, however, the tumors grow rapidly in spite of exposures.

Seabury Allen has reported three cases of epithelioma, all of which were cured; the first, of the nose and inner canthus of the eye; the second, an epithelioma of the nose, cheeks, forehead, and around the eye; the third, a rodent ulcer.

Beck says, in commenting upon an excellent result in an epithelioma of the eyelid and cheek, that he still regards "ex-

*"The Röntgen Rays in Medicine and Surgery," pp. 420, 655. Boston Med. and Surg. Jour., 1901, cxliv, p. 329.

† Med. Record, 1902, lxi, p. 83. ‡ Phila. Med. Jour., 1902, ix, p. 221.

‽ Med. Record, 1902, lxi, pp. 361, 801.

‖ Dominion Med. Monthly, 1902, xiv, p. 76.

** Phila. Med Jour., 1902, ix, p. 676.

†† N. Y. State Jour. of Med., 1902, ii, p. 176.

‡‡ Interstate Med. Jour., 1902, ix, p. 531.

‽‽ Brit. Med. Jour., 1901, ii, p. 853. ‖‖ Brit. Med. Jour., 1902, i, p. 265.

*† Brit. Med. Jour., 1901, ii, 851, 1901, i, p. 332.

*‡ Mittheil. a. d. Grenzgeb. d. Med. u. Chir., 1900, vi, p. 347.

*‽ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.

‖ Arch. f. Derm. u. Syph., 1902, lix, p. 421. † Lancet, 1901, ii, p. 144.

†‡ Loc. cit. †‽ Loc. cit. †‖ Loc. cit. ‡* Loc. cit. ‡† Loc. cit.

‡‽ Canada Lancet, 1902, xxxv, p. 526. ‡‖ Loc. cit. ‽* Loc. cit.

‽† Loc. cit. ‽‡ Loc. cit. ‽‖ Buffalo Med. Jour., 1901, xl, p. 381.

‖* Therapeutic Gazette, 1902, xxvi, p. 145.

‖† Boston Med. and Surg. Jour., 1902, cxlvii, p. 431.

tensive removal as the proper treatment. The Röntgen rays, however, should be considered in the after-treatment."

Duncan has reported one case of carcinoma of the penis in which pain and discharge were stopped. Otherwise there was no effect.

Sjögren and Sederholm state that treatment with *x*-rays is of great value when the cancer is inoperable, when it covers a large area, or when patients refuse operation.

Sjögren has reported four epitheliomata successfully treated which have had no recurrence in twelve, nine, eight, and six months respectively. Sjögren,* in another article, notes that improvement may be seen before the appearance of reaction, but that in order to obtain a cure it is necessary to induce a severe reaction producing a destruction of the diseased tissue.

Stenbeck's original case was a rodent ulcer of nine years' duration on the bridge of the nose of a woman seventy-two years old. The diagnosis in the case was made clinically, but was confirmed by Professor Berg, of Stockholm. Daily sittings were given at the start of ten to twelve minutes' duration, with moderately strong *x*-rays and with the tube at a distance of 15 to 20 cm. After about forty sittings the ulcer disappeared with the formation of a healthy scar. Stenbeck noted in this case the early disappearance of discharge from the ulcer under *x*-rays and the greater resistance to the *x*-rays offered by the nodular borders of the lesion—both facts which have been confirmed abundantly since that time.

Among the first cases reported in the United States were those of Johnson and Merrill. They included in their first report three cases of epithelioma treated by this method with symptomatic cures, concerning which in a subsequent report two years later they were able to give further details. The first case, an epithelioma one-half inch in diameter on the cheek, was symptomatically cured in October, 1899; two and a half years later the original scar remained soft and healthy. The second case was an epithelioma of the nose involving the septum which was cured in the summer of 1900; a year later there was no evidence of recurrence. The third case, a small epithelioma

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, v, p. 37.

on the tip of the nose, showed no sign of recurrence two years after its disappearance under *x*-rays. They also reported additional cases, making a list of sixteen in all. Of these sixteen, ten are apparently cured and four show improvement; of these four, three give promise of ultimate recovery under further treatment. Two cases failed to derive benefit from treatment other than relief from pain and decrease of discharge.

I have treated twenty-seven successive cases of epithelioma in which the results are now sufficiently definite to make them of interest in this connection.*

Case 46.—Mrs. ———, aged sixty-eight, referred to me by Dr. John L. Porter, with the following history, most of which is taken from the records of St. Luke's Hospital. About twenty years ago a "wart" appeared in the right supraclavicular space and gradually increased in size. Three years after its appearance the surface broke down and an ulcer developed which, after two years' duration, was excised by Dr. J. B. Murphy.

The disease recurred in the upper angle of the scar and enlarged until 1894, when she came to St. Luke's Hospital. It was then the most extensive epithelioma I have ever seen, covering almost the entire upper third of the back, and extending over the right shoulder to the clavicle. I fortunately photographed her at that time.

During 1894-95 she was in St. Luke's Hospital, in the services of Drs. John E. Owen and L. L. McArthur, where vigorous attempts were made to extirpate the diseased tissues. The tumor was destroyed and extensive grafts were made, so that the disease area over the back was converted into scar tissue, most of which remained healthy. The disease recurred in a short time, involving the area over the right shoulder, from the spine of the scapula behind to a point below the clavicle in front, an area covering the entire upper surface of the shoulders.

From 1894 until 1900 she was more or less constantly an out-patient at St. Luke's, and for the last two years it was

* Several of these cases were demonstrated after treatment before the Chicago Medical Society, February 26, 1902, and Case 46 was demonstrated before the American Dermatological Association June 1, 1901. It may be added that my lupus cases numbers 34 and 35 were demonstrated before the American Dermatological Association, June 1, 1901.

Fig. 116.—Cutaneous carcinoma. Case 46.

Fig. 117.

not thought feasible to make any further attempt at extirpation of the growth. The extent of the growth, at the time she presented herself for treatment with *x*-rays, January 15, 1901, is shown in figure 116. As shown in the photograph, the disease involved the greater part of the area over the right shoulder. The largest lesion was situated at the junction of the neck and shoulder, and consisted of three confluent ulcers, forming in all an ulcer with a diameter of about three inches. This was a typical epitheliomatous ulcer with elevated, rolled, hard, pearly borders. In addition, there were perhaps twenty other epitheliomatous ulcers, varying from the size of a finger-nail to that of a small pea, around and posterior to the large ulcer. Extending over the front of the shoulder was a triangular space with the apex below the clavicle, which contained numerous small epitheliomata. Some of these were ulcerating, but most of them were intact nodules.

All of the tissue of the affected area was inflamed and indurated. There was no evidence of involvement of contiguous glands or of the underlying tissue. There was free discharge from the ulcers and for many years the patient had suffered severe pain. Tissue for examination was excised from the border of the large ulcer and sections of this tissue presented the typical histological picture of superficial epithelioma (Fig. 118). The tissue was examined for blastomycetes, which were absent.

Through the courtesy of Dr. Porter I obtained a section that was made seven years ago. This section also showed characteristic structure of epithelioma.

The patient was put under exposures to *x*-rays on January 15, 1901, and had almost daily sittings until February 14—eighteen in all. Within a week the discharge from the ulcers almost entirely ceased, and the patient volunteered the statement that her shoulder was free from pain and that she was able to sleep comfortably for the first time in many years. After this first week there was practically no discharge from the ulcers, and almost no recurrence of pain. The disappearance of the discharge was the more interesting because before the patient came under treatment with *x*-rays she had been a regular attendant at St. Luke's Hospital out-patient depart-

ment, where her shoulder had been dressed as often as necessary.

On February 4 the ulcers were decreasing rapidly in size, and, what was more significant, the rolled edges were shrinking. On that date the patient was hurt by a fall and was not able to appear for further exposures until March 13. In the interval she was in the Charity Hospital, where, at my request, the physicians kindly saw that no change in the local treatment was made from my application of boric acid vaselin.

She returned for treatment on March 13, and from March 13 to May 4 she had twenty sittings, varying from daily sittings to sittings at intervals of from four to five days. By April 5 the evidences of epithelioma were limited to a small ulcer not larger than a little finger-nail at the site of the previous larger ulcer, and to two rows of very characteristic nodules in the supraclavicular space.

Up to this time the exposures had always been made so that the greatest intensity of light fell on the shoulder, and the lesions over the clavicle, therefore, had received less of the rays. After April 5 the upper surface of the shoulder, which had been getting exposures of fifteen minutes, was given exposures of five minutes, and the lesions over the clavicle were given direct exposures of fifteen minutes. Within five days after beginning these exposures over the nodules in the supraclavicular space a very remarkable change was noticed in them. They began to shrink and to disappear rapidly. By April 16—that is, after ten direct exposures of fifteen minutes each—these nodules had entirely disappeared. They were absorbed without dermatitis or any breaking-down. Sittings were discontinued on April 16, as the shoulder showed slight dermatitis. By April 29 this irritation had entirely disappeared. Between April 29 and May 8 the small ulcer on the upper surface of the shoulder, the last trace of epithelioma, entirely healed. Her condition on May 6 is shown by the photograph (Fig. 117).

At the time of the first publication of this case particular attention was called to the scars, which were of the excellent cosmetic character that we have since learned to expect after treatment by *x*-rays. They were hardly scars at all; the skin

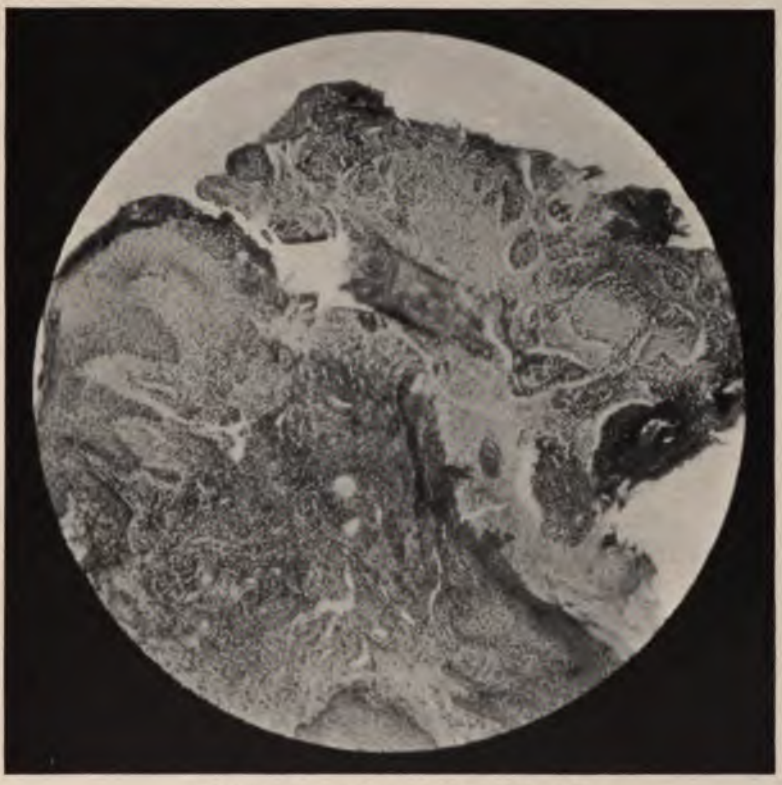


Fig. 118.—Microphotograph from Case 46.

was smooth and soft without contractures or induration, and showed hardly any trace of the previous ulcers. This patient had a few exposures after May, 1901, but never enough to have any effect.

She died September 23, 1902, from the effects of an accident. She was a very feeble old woman, living under unfavorable circumstances, and six weeks before her death fell from a high porch and received injuries from which she never rallied. There was no clinical evidence of metastatic carcinoma. A portmortem was not allowed, but I succeeded in getting the scar tissue from the shoulder at the point, and the only point, which looked suspicious. There was an ulcer the size of a pea, which on examination showed evidences of carcinoma. This small lesion could easily have been handled by any of the ordinary methods of treatment or by *x*-rays. The report of this case on September 28, 1901, was the third report of carcinoma healed by *x*-rays published in America, and was up to that time, I believe, the most extensive carcinoma treated successfully by *x*-rays that had been reported anywhere. It was reported with great detail because at the time of its publication it was extremely important to establish the diagnosis beyond question. The two reports preceding this case were those of Smith and of Johnson and Merrill. Smith had published, December 1, 1900, a case of rodent ulcer which he had cured with *x*-rays. Johnson's and Merrill's article appeared the following week.

Case 47.—Mrs. ———, aged sixty-eight, referred to me by Dr. Martin F. Engman, of St. Louis. The history of the case is as follows: Twelve years ago a small nodule developed upon the ala nasi, which ulcerated and was removed, but soon recurred. In the last ten years the lesion has been treated by almost every plan short of complete ablation of the nose, but always with prompt recurrence. In the summer of 1900 she consulted Dr. Frank Hartley, of New York, who advised a plastic operation, but she declined further operative procedures.

The condition at the time she began treatment with *x*-rays is indicated in figure 119. There was an ulcer occupying almost the entire right ala nasi and spreading down on the cheek,

a similar small ulcer was on the left ala, and between the two was an area of scar tissue, the result of previous treatment. The ulcers were typical epitheliomata in appearance; deep, with rolled, pearly borders, and fed by numerous dilated capillaries. The disease was evident within the nostrils and the walls of the nostrils were of almost papery thinness. The septum was involved and probably also the nasal bones. The ulcers bled frequently and profusely and were the source of much pain. Altogether the case seemed, both to Dr. Engman and to me, to present as unfavorable conditions for cure as possible.

She was put under daily exposures to *x*-rays April 26, 1901. By the tenth of May the borders of the ulcers were shrinking, some healthy epithelium was beginning to grow out from the edges, and the discharge was greatly lessened. By June 5 the ulcer on the left side of the nose was healed with a healthy looking scar. By the middle of June the ulcer on the right side of the nose was reduced to the size of a wheat-grain. This lesion at the point where the ala nasi was perforated was slow to heal, and the treatments were carried to the point of producing acute dermatitis, so that by August 8 the exposures were stopped on this account. After stopping the exposures the dermatitis increased until the exposed surface was denuded of epidermis. This healed in about ten days, and at the same time the last trace of the ulcer on the right side disappeared. In December, 1901, I asked Dr. T. Melville Hardie, of the University of Illinois, to examine her, and he kindly gave me the following report:

"The general appearance of the mucous membrane covering the septum and the external wall of the nostril is that characteristic of atrophic rhinitis. The membrane is in nearly every place thinner than normal and there are numerous spots where there is present a slight dried oozing of blood, which follows the removal of the crusts of dried mucus. This condition is more obvious in the right nostril, but this is the case partly because of the partial obstruction in the left nostril caused by a deflection and ridge of the septum.

"The right inferior turbinated bone is smaller than normal, the atrophy having extended to the bone, besides affecting the

Fig. 119.—Carcinoma of the nose.

Fig. 120.

mucous membrane covering it. The anterior end of the middle turbinated body is enlarged and the mucous membrane covering it is atrophic. Careful examination discloses no ulceration in the nostril and no infiltration, the only irregular feature of the diseased portion being the over-red color of the mucous membrane of the floor and the inferior turbinated body. The nasopharynx also exhibits atrophy of its mucous membrane and bleeds when the crusts of dried mucus are forcibly disturbed."

All of the scar tissue has remained healthy, and the only trace of disease that has reappeared was a little mass the size of a pea that gradually developed above the scar half an inch below the inner canthus of the right eye. This was very hard and attached to the periosteum. It was removed on my advice in October, 1902, and was found to contain some carcinomatous tissue. The condition at present is shown in figure 120. The result in this case may be regarded, I believe, with entire satisfaction in spite of the small recurrence. Without *x*-rays the chance of relief was very remote and possible only at the expense of a disfiguring operation. With *x*-rays the nose has been saved and the only operation necessary reduced to one of minor character.

Case 48.—Healthy man, aged thirty-eight. In November or December, 1900, there appeared on his nose at the site of a previous wart an indurated nodule which ulcerated and spread rapidly. In May, 1901, he came to my clinic at the College of Physicians and Surgeons. The condition at that time is shown in figure 121. There was an ulcer involving the tip of the nose the size of a five-cent-piece. Sections taken from the borders of the ulcer confirmed the diagnosis of epithelioma (Fig. 123). It was an epithelioma situated deep in the subcutaneous tissue, showing many pearls and growing rapidly.

He was put under *x*-ray treatment May 23, 1901, and was given exposures more or less regularly for two and a half months. There was a healthy scar by September 15. His condition at that time and at present is shown in figure 122.

Case 49.—Healthy man, aged seventy-three, referred to me November 5, 1901, from the Illinois Eye and Ear Infirmary, for treatment of the ulcer shown in figure 124. This was a

sharply punched-out ulcer in the right nasal furrow the size of a little finger-nail, with raised, waxy borders and profuse blood-supply, and painful. The disease began about two years ago in a warty growth, which bled easily. I got no section of it, but it was in appearance a typical epithelioma, and there is no doubt of the diagnosis. The result after three months' treatment is shown in figure 125. There is a smooth, soft, white, healthy looking scar, without induration.

Case 50.—Man, aged seventy-five, referred to me by Dr. Norval H. Pierce, Surgeon to Illinois Eye and Ear Infirmary, with an epithelioma of eleven years' duration. It involved the auditory canal for its external one-third, and the entire inner surface of the concha, and had spread for half an inch upon the cheek, the tragus having been destroyed. He was put under *x*-ray exposures November 5 and treated daily to December 5, 1901, when some erythema developed and the ulcer began to heal. The sittings were nevertheless continued to January 25, 1902, when there developed marked congestion and later a superficial burn of the exposed area. This gradually subsided, and with its subsidence the ulcer healed. Since April, 1902, the entire site of the epithelioma has been covered with healthy skin. In September, 1902, a small nodule appeared in the concha; I destroyed this successfully with Bougard's paste and a healthy scar quickly formed.

Case 51.—Mrs. ———, aged sixty-one, referred to me by Dr. M. F. Engman, of St. Louis. About twelve years ago a lesion developed on her forehead above the right eye which was recognized as an epithelioma. Two years ago it had developed into an ulcer the size of a half-dollar, and in November, 1899, she went to Dr. William T. Bull, of New York city. Dr. Bull has kindly given me his memoranda of the case, as follows: "Circular ulcer of forehead in center and reaching to eyebrows as large as fifty-cent-piece. Edges slightly elevated and hardly movable. This appeared first ten years ago as an indurated nodule and was destroyed by caustics. It reappeared and was cut out three times—the last time four years ago. At operation [Dr. Bull's] the ulcer, with a wide margin of skin, was removed and the raw surface covered with four skin-grafts. Healing was

Fig. 121.—Cutaneous carcinoma. Case 48.

Fig. 122.

Fig. 123.—Microphotograph from Case 48.

Fig. 124.—Cutaneous carcinoma.

Fig. 125.

complete in three weeks. Dr. Dunton examined the tissue removed and pronounced the growth an epithelioma." After Dr. Bull's operation the scar remained healthy until September, 1901, when two small ulcers developed in the border of the scar.

When she came under my care, November 14, 1901, there was on the forehead, above the left eyebrow, a healthy looking scar 2 by 2 inches. On the external border of the scar there were two small ulcers, one at the upper outer angle the size of a little finger-nail, the other at the lower outer angle somewhat smaller, presenting the picture of typical small epitheliomata. The upper half of the inner border of the scar was occupied by a red indurated scaly patch an inch long by half an inch broad, around which were numerous dilated capillaries. This presented the picture of an inflamed patch of senile keratosis undergoing degeneration into epithelioma.

She was given exposures daily over the patch and over the ulcers until the lesions became somewhat inflamed, and afterward the dermatitis was kept at this stage. By December 8, 1901,—approximately a month,—the ulcers were healed, and by January 8—two months—the induration had entirely disappeared. The skin at the site of the ulcers is smooth, perfectly soft, and free from induration. The site of the patch of verruca senilis on the inner border of the scar is still slightly red as a result of the exposures, but it is smooth and soft and the induration has entirely disappeared. There has been no recurrence.

Case 52.—Mrs. ———, aged fifty, with an epithelioma of five years' duration as shown in photograph (Fig. 126). The disease involved an area on the side of the nose and around the inner canthus as large as a fifty-cent-piece. There were two ulcers in the area, one the size of a finger-nail on the side of the nose, the other half that size at the inner canthus. The ulcers were sharply excavated, with elevated, rolled, nodular borders, and around them the tissue was indurated and waxy looking. It was a typical small rodent ulcer, such as is often seen in this location, but no tissue was gotten for examination. The result March 1, 1902, after two months of treatment, is

shown in figure 127. There is practically no scarring; the skin is white and smooth and there is no induration. It would be hard to say that any ulcer had existed. The case illustrates the ease with which lesions about the eye can be treated with *x*-rays.

Case 53.—Spare-built man, aged thirty-five, referred to me by Dr. T. J. Knudson, from St. Luke's Hospital. Eleven years ago a small nodule appeared on the right cheek, below the eye, which gradually increased in size and after two years ulcerated. The lesion was treated from time to time by different surgeons in various parts of the United States. Four years ago he was admitted to Cook County Hospital in the service of Dr. T. A. Davis. Dr. Davis did a radical operation, removing the ulcer and a large amount of the surrounding tissue and restoring the lower lid by an extensive plastic operation. At the end of a year the disease recurred in the scar and rapidly enlarged, involving the orbit. During the winter of 1899–1900 he was in the Cook County Hospital in the service of Dr. Charles Adams. The disease had then attained such an extent that a radical operation was not undertaken.

When he came to me, the disease involved the entire orbit, the upper and lower lids, the side of the nose, and the cheek. A shrunken atrophic globe remained, which was retracted deep in the orbit. Before undertaking treatment by *x*-rays Dr. W. H. Wilder at my request removed the eye on December 5. No attempt was made to destroy the carcinoma in this operation, and on December 14, 1901, he returned for *x*-ray exposures. The accompanying photograph (Fig. 128) does not adequately show the condition at that time. A microphotograph of a section of the tissue taken from the lower lid two weeks later is shown in figure 93, page 267, and confirms the diagnosis of epithelioma. At this time the patient was suffering exquisite pain, which had not been relieved by removing the eye, and from anxiety, pain, and loss of sleep his physical condition was greatly reduced. He was put under *x*-ray treatment December 14, and had almost daily sittings to January 27, 1902. The exposures were carried to the point of producing erythema and slight desquamation, but no weeping. Within a week after beginning

Fig. 126.—Cutaneous carcinoma.

Fig. 127.

Fig. 128.—Carcinoma of the orbit.

Fig. 129.

the treatment his pain had ceased and the discharge began to diminish. After that time the improvement was continuous. The borders and the nodules gradually shrank and the ulcers became smaller and finally healed over. The condition just before healing became complete is shown in figure 129. The patient was free from pain practically from the beginning of the treatment and entirely regained his health and spirits. March 1, 1902, this patient disappeared, and was not seen again until August 6, 1902, when he appeared with a round ulcer at the inner angle of the eye ¾ of an inch deep and half an inch in diameter. This has been vigorously exposed and is now greatly improved.

Case 54.—Woman, aged forty, with a superficial epithelioma on the cheek an inch below the right eye. The lesion had appeared three years before and gradually enlarged. At the time she came under treatment there was a superficial lesion the size of a thumb-nail, consisting of scar tissue resulting from previous application of caustics and a periphery of indurated nodules supplied by numerous dilated blood-vessels. She received twelve *x*-ray exposures between February 24 and March 8, 1902, each at a distance of 5 cm. and of fifteen minutes' duration. On March 8 an acute dermatitis developed, which disappeared by March 31. With its disappearance all of the nodules entirely disappeared. Eight months later the scar remained smooth and healthy.

Case 55.—Man, aged forty-one, referred to me by Dr. Edmund Pinchon, of Chicago, with an epithelioma on the tip and ala of the nose an inch in diameter. It began in 1883 as an indurated nodule, which soon formed a small ulcer. This grew very slowly and in 1893 had reached one-half inch in diameter. It was then cauterized, and healed, but recurred in about a year. The second ulcer was excised by Dr. Christian Fenger, and after nine months recurred. At the time of coming under observation there was an ulcer about half an inch in diameter with rolled indurated edges situated on the left ala nasi. The diagnosis of carcinoma was confirmed microscopically. The ulcer was situated at the border of a scar about an inch in diameter occupying the entire tip of the nose, the result of the

previous operation. The area was given thirteen exposures at a distance of 5 cm. and of fifteen minutes' duration each between March 12 and April 25, 1902. On April 14, before the development of any marked erythema, the ulcer had healed with a healthy scar, and eight months later remains well.

Case 56.—Woman, aged sixty-five, with an epithelioma the size of a split pea on the forehead. This was exposed to *x*-rays to the point of producing an acute dry dermatitis, with the disappearance of which the lesion disappeared leaving an almost imperceptible white scar. This case has been well since March 29, 1902, eight months.

Case 57.—Man, aged forty-five, referred to me by Dr. C. D. Westcott, of Chicago. Three years ago a mole about the size of half a wheat-grain, which he had always had on the lower left eyelid, became indurated and then ulcerated, and in spite of treatment upon several occasions with caustic pastes gradually increased. At the time that he came under my care the disease had spread until it involved the entire lid. The palpebral border was destroyed throughout its full extent, and along the line of juncture between the skin and the mucous membrane there was a string of characteristic hard waxy nodules. There were several tubercles also involving the juncture of the mucous membrane and conjunctiva, so that the distance of the cornea from the nearest nodules was very short. In this case great care was taken in giving the exposures to avoid striking the eye. A mask was made to cover the whole face and shaped to the curve of the eye with a crescent-shaped opening in it to correspond to the area to be exposed. The diseased border was pulled as far down as possible, but owing to the attachment to the conjunctiva this manœuvre was of little effect. The exposures were also given slightly from above to avoid striking the conjunctiva. Between April 3 and May 7, 1902, he received thirty exposures at an average distance of 8 cm. and of an average length of seven and a half minutes. On May 7 it was noted that "there is some irritation of the lower lid, but no conjunctivitis. Nodules shrinking." On May 16 I made a further note: "Irritation practically gone. Nodules on lower lid considerably smaller." On May 16 exposures of similar

length and intensity were renewed and given daily until May 31, when, on account of slight conjunctivitis, they were stopped. This conjunctivitis was very slight and rapidly disappeared, and the exposures were renewed on June 9 and given daily until July 2. On July 2 the lid became red and congested and exposure was stopped. The lower quadrant of the conjunctiva was slightly injected up to the edge of the cornea. By this time the border of the lid was perfectly soft and free from induration. After that date he had no further exposures. The irritation quickly subsided and left a smooth, soft, healthy looking lid.

Case 58.—Mrs. ———, aged sixty. Thirty years ago a small indurated nodule developed on the cheek an inch below the inner canthus of the right eye. The growth gradually increased and eight years ago ulcerated. Since that time it has been treated repeatedly with caustics, the last treatment of this sort being a year and a half ago, when it was removed by caustics and promptly returned. At the time that she came to me there was a large epithelioma involving the cheek, the side of the nose, and the inner canthus of the right eye. The condition four weeks after the beginning of treatment, when most of the ulcer had healed, is indicated in figure 130. At the time of beginning treatment there was an ulcer with hard nodular borders an inch and a half in vertical diameter and three-fourths of an inch in transverse diameter. The upper and lower lids each had pea-sized nodules on the inner surface. Exposures were begun on April 16, 1902, and between that date and July 23 she received forty exposures at an average distance of 5 cm. and of five minutes' duration. Great care was exercised in exposing the nodules on the lids and avoiding at the same time the cornea. On April 29 an acute dry dermatitis developed. The following memoranda made at the times indicated show the subsequent course of the disease: "May 7: Irritation subsiding slowly. Healing. Lower eyelid slightly inflamed and puffy." "May 17: Irritation gone" (no exposures having been given since April 29). [illegible] dermatitis was produced, and [illegible] in the growth. On July 2 [illegible]

condition at that time is shown in figure 131. The scar was smooth and healthy looking. On the edge of the lid near the angle of the eye there was a point still slightly indurated. A small tubercle developed there October 1, 1902, which disappeared promptly under exposures. The entire scar had a perfectly healthy appearance.

Case 59.—Woman, aged sixty-four, referred to me by Dr. E. W. Marquardt, of Chicago. Fifteen years ago an ulcer began on the forehead, which gradually spread until at the time of coming under my care it was of the extent shown in figure 132. It occupied the entire forehead, spread down over the upper two-thirds of the nose, involved both eyebrows, half of the right upper lid, and the entire left upper lid. It also involved the inner canthus of the right eye, both canthi of the left eye, and about half of the left lower lid. The left upper lid was very much thickened and indurated, so that the eye had been closed for over two years. The diagnosis of carcinoma was confirmed by microscopic examination. This patient received forty exposures between May 1 and July 1, 1902, at an average distance of 10 cm. and of an average duration of ten minutes. The ulcer began to show improvement promptly. On June 21 the memorandum was made that the "ulcer has been showing great improvement; healing at edges for more than a week past." The condition on June 7 is shown in figure 133. From this time on the improvement was gradual. On July 10 exposures were discontinued because of the development of a severe conjunctivitis in the left eye, which, on account of a disappearance of induration in the upper lid, could now be opened. She received no more exposures until August 25. In the mean time the improvement in the disease continued, so that by August 25 there was no disease left except a small ulcer on the center of the forehead about an inch long and an inch and a half wide, which presented none of the appearances of a carcinoma. Since August 25 she has had occasional exposures over the forehead. The small ulcer healed in October, and with its disappearance the last evidence of the disease vanished. The condition March, 1903, is shown in figure 134.

At present the entire area is covered with smooth, white,

Fig. 130.—Cutaneous carcinoma. Extent at the beginning of treatment is indicated by the dotted line

Fig. 131.

Fig. 132.—Cutaneous carcinoma.

Fig. 133.

Fig. 134

healthy looking skin. The skin of the lids and nose is in color and pliability like the skin of a young person. There is no contraction such as would be expected in scar tissue. The eyelids are perfectly pliable and as freely movable as normal lids. The loss of the eye in this case is possibly attributable to a conjunctivitis due to *x*-rays, but is probably not. It must be remembered that this eye had been bathed in pus for a long time and had a chronic conjunctivitis with scars on the cornea, and it is entirely possible that the acute inflammation of the eye that destroyed the cornea was due to infection that occurred after she became able to open the eye. Even granting that the loss of the eye was due to *x*-rays, it militates little against the excellence of the result. The eye had already been out of use for two years, and would certainly soon have been destroyed by the carcinoma had it not been checked. The disease had gotten beyond the point of treatment by any other method, unless both eyes were to be sacrificed.

Case 60.—Man, aged sixty-five, with a superficial epithelioma on the left cheek in front of the ear. The lesion was triangular in shape, a little larger than a fifty-cent-piece, and consisted of scar tissue the result of previous operations, of indurated nodules, and of several superficial ulcers. It began eight years ago in front of the ear and had progressed very slowly. The diagnosis of carcinoma was confirmed microscopically. The patient was given fifteen exposures in three weeks with the production of an acute dry dermatitis on May 24, 1902. The patient then went to his home and was put under the care of Dr. S. B. Childs, of Denver. One month later Dr. Childs wrote me that the large area had been healed for several days and that "there are only two very small nodules about the small area." The case has been subsequently treated by Dr. Childs, and there has been a healthy scar since July 1, 1902.

Case 61.—Man, aged fifty-seven, referred to me by Dr. H. H. Powell, of Cleveland, Ohio. The condition at the time of beginning treatment is shown in figure 135. There was a hard raised tumor one and a half inches in diameter and a fourth of an inch high occupying the glabella. It began several years before in a small nodule on the forehead, but had grown rapidly only

within the last year. The diagnosis of carcinoma was confirmed microscopically. This patient received 27 treatments between June 7 and July 25, 1902, without at any time the production of a perceptible reaction. Very soon after beginning exposures the tumor began to shrink, and just one month afterward I made the memorandum: "Carcinoma nodules have shrunken so that the surface is flat. It has healed over with healthy scar tissue except for an area about the size of a finger-nail, which shows a healthy granulating surface." Six weeks after beginning treatment it was entirely healed, with a soft white smooth scar. The condition since July 25, 1902, is shown in figure 136.

This case is illustrative of the type of epithelioma which is most susceptible to the effect of *x*-rays. A tumor mass three-eighths of an inch thick or more and one and a half inches in diameter simply melted away and was replaced by healthy skin, without at any time the production of any pigmentation or any erythema. Were there no other similar results, this one case would be sufficient to disprove the statement that an *x* ray burn must be produced in order to get rid of carcinomatous tissue. The case shows an ideal reaction to *x*-rays—a reaction sufficient to cause degeneration and disappearance of the diseased tissue without any damage to the healthy tissue involved in the lesion. The result of the disappearance of the carcinomatous tissue without destruction of the healthy stroma is shown in the small amount of scarring. Less scarring with the destruction of a lesion of this extent could hardly be possible.

Case 62. Man, aged sixty-five, with an epithelioma of several years' duration the size of a finger-nail in the right nasal furrow. The patient was a physician and the diagnosis of epithelioma had been made by numerous physicians. This patient had nine daily exposures between June 24 and July 3, 1902, with the tube at a distance of 3 cm. from the surface and of an average duration of twelve minutes. Five days after the exposures were discontinued a dermatitis appeared, which became quite acute one week later, and then began to subside. In two weeks more it had entirely disappeared, and four weeks after discontinuing the treatment all of the induration had disappeared, and a

Fig. 135.—Cutaneous carcinoma.

Fig. 136.

healthy scar had formed. The erythema did not entirely fade out for two months. At the present time—seven months later—there is a healthy, small, inconspicuous scar.

Case 63.—Man, aged thirty-two, referred to me by Dr. McGregor, of Central Lake, Mich. In July, 1900, he noticed a warty growth on the prepuce which gradually enlarged and grew very painful. In February, 1902, the prepuce was removed by Professor Nancrede, of the University of Michigan. The disease promptly recurred, and he was then treated by plasters without result. At the time that he was referred to me there was a fungating growth the size of a five-cent-piece on the right side of the glans and prepuce. On the left side there was a similar lesion on the glans and prepuce, following the curve of the corona, an inch long and five-eighths of an inch broad. These masses were hard and indurated and in places ulcerating. The diagnosis of carcinoma was confirmed microscopically. The inguinal glands were just palpable. Exposures at a distance of 5 cm. and of an average duration of eight minutes were begun over both masses on July 8, 1902, and were continued daily until July 31, with the production of a slight dermatitis on several occasions.

Exposures were stopped July 31 on account of a dermatitis which remained until there was a superficial necrotic membrane over the area exposed. This gradually healed and epidermis had formed over the area by September 15. Under the influence of the burns the lesions gradually shrank away, until by October 1 they had entirely disappeared. There was practically no scarring. The contour of the parts was normal and there were no suspicious points. During the time of treatment he also received exposures over the inguinal regions. He has been symptomatically well since October 1, 1902.

Case 64.—Man, aged sixty-seven, with an ulcerating epithelioma the size of a twenty-five-cent-piece on the left cheek, as shown in figure 137. This began in a patch of senile keratosis four years before. When the ulcer first formed, it was the size of a finger-nail, and gradually increased. The diagnosis of carcinoma was confirmed by microscopic examination. This case was cured by fifteen *x*-ray exposures between July 12 and

August 15, 1902 (Fig. 138). This case is further considered under Senile Keratosis, page 566.

Case 65.—Woman, aged sixty-five, referred to me by Dr. Geo. W. Newton, of Chicago, with an epithelioma the size of a finger-nail on the tip of the nose, of two years' duration. The lesion at the time of beginning treatment consisted of two small ulcers surrounded by typical indurated pearly borders. Between July 12 and July 31, 1902, she received thirteen exposures at a distance of 5 cm. and of an average length of twelve and one-half minutes. August 1 dermatitis developed, which became a bright red at the end of a week, remained stationary for another week, and then rapidly subsided. With its subsidence the lesion disappeared, and on August 27 was replaced by a smooth, healthy, almost invisible scar.

Case 66.—Man, aged sixty-seven, referred to me by Dr. Rickey, of Grey's Lake, Ill., with an epithelioma on the bridge of the nose, one and a half inches long and three-fourths of an inch broad, of four years' duration (Fig. 139). This lesion was given sixteen exposures between July 17 and August 29, 1902, with the development of a slight dermatitis. The lesion began to decrease rapidly in size on August 14, and by September 1 was replaced by a smooth healthy scar (Fig. 140). This case is considered further under Senile Keratosis, page 566.

Case 67.—Woman, aged seventy, referred to me by Prof. William E. Quine, of the University of Illinois. Fifteen years ago a small nodule developed on the cheek, which was removed thirteen years ago by Dr. Edmund Andrews. It recurred promptly and gradually increased in size. At the time that she was referred to me there was an epithelioma the size of a fifty cent-piece on the nose and cheek below the left eye. The borders were raised and indurated, but there was little ulceration. On the top of the head there was an elevated ulcerating epithelioma almost circular in outline and 1¾ inches in diameter. The diagnosis of carcinoma was confirmed microscopically. Between July 28 and August 11, 1902, each area was given twelve exposures at 5 cm. and of five minutes' duration. A trace of erythema developed upon both lesions on August 11, and exposures were discontinued until August 27. Between August 27 and Septem-

Fig. 137.—Cutaneous carcinoma with senile keratosis.

Fig. 138.

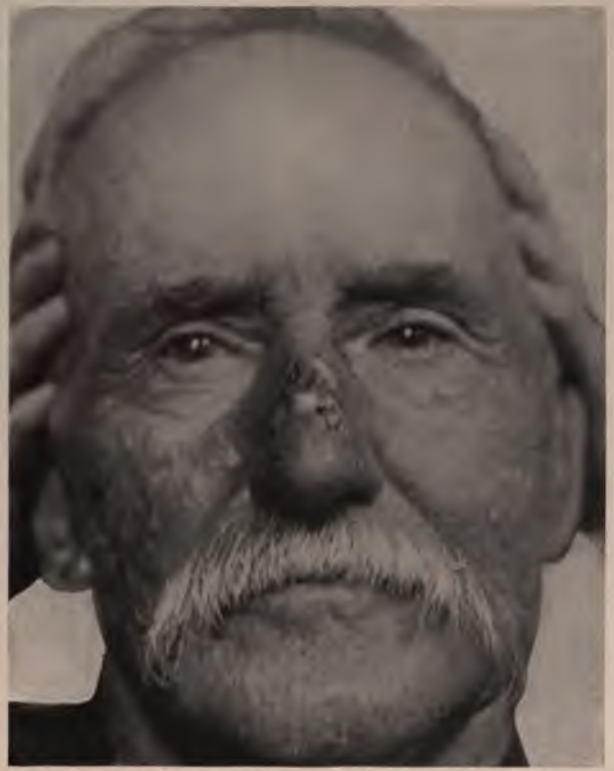


Fig. 139.—Cutaneous carcinoma with senile keratosis.

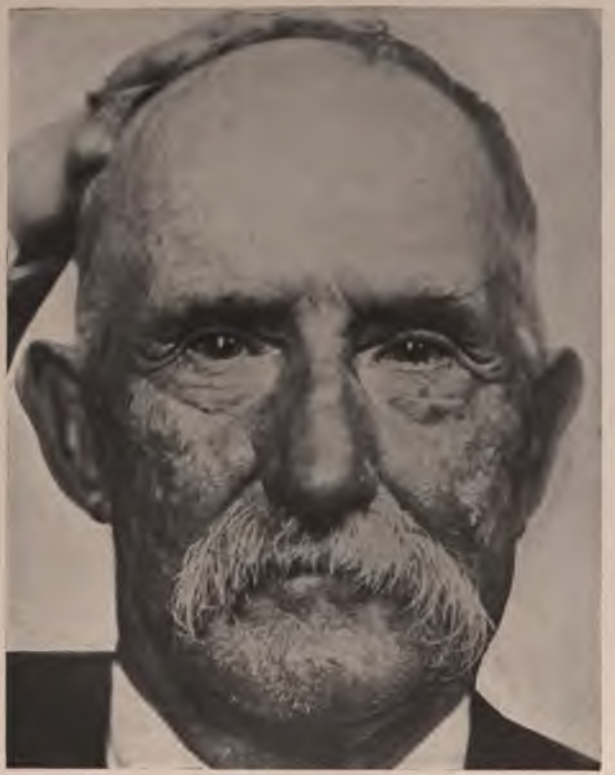


Fig. 140.

ber 29, twelve exposures were given at a distance of 5 cm. and of five minutes' duration. Under these exposures both lesions cleaned up rapidly. On the face the nodules shrunk and disappeared. On the scalp the ulcers sank to the level of the normal skin, dried up, and rapidly became smaller. On October 1 the ulcer on the top of the head had entirely healed. It was replaced by smooth, perfectly healthy looking scar tissue with no suspicious nodules at any point. A similar transformation had taken place in the lesion on the face. All the nodules are gone and the scar remaining is slight.

Case 68.—Man, aged sixty-two, referred to me by Prof. J. B. Murphy, of Northwestern University. Ten months ago a little nodule appeared on the outer half of the lower right eyelid. Other nodules developed until the outer half of the lid was involved. The disease had been treated by electrolysis, and excision had been advised. The condition at the time of his coming to me is shown in figure 141. There was a group of hard, waxy nodules involving nearly the entire outer half of the palpebral border of the lower lid. The conjunctiva was not involved. The mass was a little over 1 cm. long and half as thick. At one point there was an ulcer the size of a split pea. The diagnosis of epithelioma had been made by Dr. Murphy and others and was above question. This patient received forty-two exposures between August 15 and October 4, with the development at times of slight dermatitis and gradual shrinking of the lesions, until by September 15 no nodules remained. The treatment at the last was carried to the point of producing a slight superficial *x*-ray burn, which rapidly healed and left a smooth, soft, healthy looking scar, as shown in figure 142. The lid is normal in appearance, and without distortion.

Case 69.—Mr. ———, aged ninety-eight, referred to me by Dr. E. J. Dohring, of Chicago, with a superficial, freely movable epithelioma, the size of a little finger-nail, on the tip of the nose. This lesion was given fifteen moderate exposures between August 18 and September 3, 1902, with the production of a [illegible]itis, after which the exposures were stopped. Its [illegible]o weeks was accompanied by the formation [illegible]e of the epithelioma. This patient

had several patches of senile keratosis on the face; two of these the size of a finger-nail, were inflamed and showed beginning carcinomatous degeneration. Each of these was given six exposures of five minutes at 5 cm. distance between September 8 and September 15, and one exposure on September 15 at 5 cm. of fifteen minutes' duration. These exposures were followed in either patch by slight dermatitis, which resulted in exfoliation of the horny masses and in leaving the areas smooth and soft, with the appearance of healthy skin.

Case 70.—Man, aged fifty-eight, referred to me by Dr. R. J. Mitchell, of Girard, Ill. His condition at the time of coming to me is poorly shown in the accompanying photograph (Fig. 143). There was a tumor an inch in diameter and over half an inch high on the left lower lid. There was a profuse purulent discharge which had caused a severe conjunctivitis. The pain was severe and required the use of anodynes. The case had been treated previously—once by excision, and from March to June, 1902, vigorously by caustics—and since June had grown very rapidly. Between August 21 and September 22, 1902, he received twenty-six *x*-ray exposures, at an average distance of 6 cm. and of an average duration of ten minutes, with the production in the end of a slight dry dermatitis. The effect of the *x*-ray exposures was very prompt. After ten exposures he had no more pain and the tumor began to shrink rapidly. Without further exposures the lesion gradually disappeared, and by October 15 was replaced by a healthy scar. There is no ectropion and the eye is not damaged (Fig. 144).

In treating this case I was hampered by the existence of a very acute conjunctivitis, with chemosis, caused by the constant bathing of the eye with pus from the ulcerating tumor, and there was imminent danger of ulceration of the cornea. The eye, therefore, was protected very carefully against the *x*-rays. This conjunctivitis was treated with boric acid and protargol in the usual manner, and by the time the tumor had disappeared the conjunctivitis had also disappeared.

This patient also had a beginning superficial epithelioma of the lower lip, involving almost its entire extent, which unfortunately does not show well in the photograph. For this he was

Fig. 141.—Carcinoma of the lower eyelid.

Fig. 142.

Fig. 143.—Carcinoma of the lower eyelid and lower lip.

Fig. 144.

given fourteen exposures at an average distance of 6 cm. and of an average length of eight minutes. A quite acute dermatitis was produced, which was followed by the exfoliation of the thick horny masses covering the lesion and the subsequent smooth healing of the lip. The lip since October 1 has been smooth and soft and free from suspicious points, and without perceptible scar. The present condition of the patient is shown in figure 144.

The next three cases are placed out of their chronological order because they can be considered more conveniently last.

Case 71.—Woman, aged sixty, referred to me by Dr. A. E. Baldwin, of Chicago, with an enormous epithelioma which had destroyed the left eye and eyebrow, involved the entire orbit, spread down over the cheek to the level of the nostrils, involved the entire left side of the nose, and extended over the right side of the nose almost to the inner canthus of the right eye. The disease developed many years ago and had been operated upon several times and treated numerous times with plasters. The present ulcer had been growing for seven years. The eye had recently been destroyed by the process, and at the time of beginning treatment she was suffering great pain. The condition at the time of beginning treatment, January, 1902, is shown in figure 145. From January 20, 1902, to December 1, 1902, this patient has had more or less constant treatment. She has had treatment every other day for periods of three or four weeks, and then remissions for a while, followed by further periods of treatment. Promptly with the beginning of treatment the pain disappeared and the ulcer began to contract. The condition at the present time and for several months past is shown in figure 146. There is no induration of the borders of the ulcer, and indeed no nodules can be found at any point. The course of the disease has been practically checked from the beginning of treatment. Whether it will ever be possible to fill up this large deep cavity is altogether doubtful, but the result illustrates what may be done in checking so desperate a case. The patient has suffered almost no pain since ten days after the beginning of treatment. The disease not only has not spread, but its borders have been very much reduced. The right eye, which bid fair to become involved very quickly, has been saved. Altogether, from an

aggressive rapidly spreading destructive process the condition has been changed into an inactive ulcer which has lost almost all of the qualities of malignancy.

I have treated one, and only one, case of epithelioma, which must be set down as a failure, after a fair trial:

Case 72.—Man, aged sixty-five, from the Illinois Eye and Ear Infirmary. This patient had a very deep-seated epithelioma, extending across the root of the nose and involving the inner canthus of the right eye. The lesion was nearly an inch long, less than half an inch wide, and quite deep (Fig. 147). This patient has been persistently treated from February 24, 1902, and the reaction has been carried several times to the production of an acute burn with superficial necrotic membrane. Apparently there has been no effect, except to prevent spreading. The lesion has not increased in size, but it has not decreased; and, more significant still, I have been unable to get rid of all the nodules. Why this has been so in this case it is hard to explain. It is perhaps a question altogether of idiosyncrasy. There is nothing in the character of the tumor to indicate that it differs in any respect histologically from numerous carcinomata which have promptly yielded. The case illustrates the fact that carcinomata differ, as do patients, very markedly in their susceptibility to *x*-rays. The only effect, thus far, in this case has been the checking of the growth and the relief of pain. The patient formerly suffered extreme pain, which ceased after the first *x*-ray reaction. The case is still under treatment. [Within the last month, since the above was written, there has been very great improvement in this case, so that there is apparently a good chance of cure. The improvement is manifest on comparing his condition December 18, 1902 (Fig. 148), with figure 147.]

Case 73.—Figures 149, 150, and 151 are inserted to illustrate the changes seen in a rapidly growing deep-seated carcinoma of the skin under treatment. In figure 149 are seen the nodular masses on the cheek which indicate a severe type of cutaneous carcinoma. In figures 150 and 151 is seen the ulcer, healing under treatment; the nodular masses have entirely disappeared,

Fig. 145.—Carcinoma of the orbit.

Fig. 146.—Condition under *x*-ray exposures.

Fig. 147.—Carcinoma of the nose and inner canthus.

Fig. 148.

Fig. 149.—Cutaneous carcinoma, September 1, 1902.

Fig. 150.—November 1, 1902.

Fig. 151.—December 1, 1902.

and in their places we have an apparently benign clean ulcer, whose borders are rapidly contracting.

Of the above twenty-seven cases, twenty-one, or 77.7 %, are, as far as can be told by their present condition, cured—numbers 48, 49, 51, 52, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70. Of these twenty-one cases, seven have been well eight months or more, as follows:

Case No. 48 has been well 15 months.
" " 49 " " " 10 "
" " 51 " " " 11 "
Cases Nos. 52 and 54 have been well 9 months.
" " 55 and 56 " " " 8 "

The length of time that the remaining fourteen have been well varies from six months to a few weeks. Of course, sufficient time has not elapsed to judge as to the permanency of the results, but from the results in the cases which have gone longest, and from the character of the scars, I think there is no doubt that these scars will not show any larger proportion of recurrences than is seen in favorable cases of epithelioma treated by other methods. And of these cases by no means all were favorable cases for surgical operation. Cases 49, 54, 56, 62, and 65 were insignificant epitheliomata that might easily have been handled by any method of treatment. Perhaps the advocates of the use of pastes in the treatment of epithelioma would say that also Cases 48, 51, 55, 64, 66, and 69 could have been handled as well by the use of caustic pastes, but they could not have been handled more successfully, I am sure, and there would have been more scarring, to say nothing of the pain of the treatment. Cases 60, 61, 66, and 67 would have required rather extensive plastic operation to get rid of them surgically. Cases 52, 58, 59, 68, and 70 were all epitheliomata involving the eyelids, and their surgical treatment would have required the plastic restoration of the lids, and the sacrifice of the eye in some of the cases. Case 63 was a carcinoma of the penis which had failed of treatment both by caustics and by surgical operation. Indeed, while many of these cases would be considered amenable to ordinary treatment, the fact remains that a good proportion of them had

had other forms of treatment at competent hands without success.

Of the four cases which show recurrence, only one has shown a recurrence comparable in severity with the original disease. This was Case 53, and it was entirely inadequately treated, through the negligence of the patient. The other three cases were cases which presented grave obstacles to surgical treatment. Cases 46 and 47 had failed of cure in the hands of most competent surgeons. It had not been regarded as feasible in Case 46 to make any further attempts at treatment, and in Case 47, which had had vigorous surgical treatment in competent hands extending over many years, the only surgical measure left was the total removal of the nose, which the patient refused. The recurrence in Case 46 was only an epithelioma the size of a small pea, which would have offered no difficulty of treatment by *x*-rays or curetting or caustics, or any other method. In Case 47 the nose has been saved. For several years previous to beginning treatment the entire nose had been ulcerating, and this had necessitated the wearing of an unsightly bandage all the time. All that trouble has been escaped, and the only recurrence has been a small subcutaneous nodule below the eye, which required only a simple operation for its removal. Case 50, which involved the auditory canal for its external half inch, and a large part of the external ear, would have required for its relief the destruction of the external ear and an extensive destruction of tissue in order to get rid of the epithelioma in the auditory canal. It was practically inoperable. The only recurrence in this case was a small lesion the size of a French pea in the concha, which, for convenience, I destroyed with Bougard's paste, and which gave no trouble. Case 59 was totally beyond relief by any other method, and the result is a striking illustration of the possibilities of this method. Without *x*-rays nothing was left for this patient except the prospect of destruction of the face and a miserable end.

Two of the cases still show some lesion—Cases 71 and 72. Case 71 was beyond the point of successful treatment otherwise. Its course has been checked and the patient's suffering stopped, a result that may be regarded, I believe, as satisfactory. Case

71 is a failure that must be charged against the method. [Subsequent developments in this case indicate that my estimate of it was too conservative, as it is now almost well (see Fig. 148).]

In 26 of the 27 cases, or 96.35 %, this method of treatment has done, I believe, all that could be fairly expected of it or of any other method. When there is some fact to detract from the completeness of the results, it is due rather to some insuperable difficulty in the case than to any inadequacy of the method. Only one case can be charged up against the method as an unmitigated failure; and a record of only 3.75 failures in cases which presented such difficulties as these did is, it would seem, a satisfactory showing.

The cosmetic excellence of the scars after treatment with *x*-rays has been noted by many observers. There is less scarring than follows any other method of treatment, and the scars that do occur are soft, smooth, of the color of the normal skin or white, and entirely healthy looking. The fact that practically no destruction of healthy tissue takes place is a marked advantage of the method in treating lesions at points where there is little tissue to be spared, as about the eyelids.

CHAPTER XII.

CARCINOMA OF THE BREAST AND IN THE THORAX.

Carcinoma of Breast.—There are now a considerable number of reports in the literature upon the use of *x*-rays in the treatment of carcinoma of the breast, and at the present time there is every evidence that the method is being given a very wide trial, much wider than the extent of the literature upon the subject would indicate. Among those who have treated carcinoma of the breast by this method are Gocht,* Hopkins,† C. W. Allen,‡ Eijkman,§ Johnson and Merrill,‖ Morton,** Ayers,†† Clark,‡‡ Soiland,§§ Williams.‖‖

So long ago as 1897 Gocht reported two cases of inoperable mammary carcinoma which he had exposed to *x*-rays. The first case received six daily exposures, with almost entire relief of pain. In the second case death took place before improvement could be expected.

Hopkins has reported two cases of carcinoma of the breast treated by this method. The first case was a primary carcinoma of the breast in which the involved breast was twice as large as the other and after thirty-two treatments decreased to practically its normal size; in the mean time all subjective symptoms ceased. In the second case, an ulcerating carcinoma of the breast, there has been disappearance of pain and odor and decrease in size.

* Fortschr. a. d. Geb. d. Röntgenstrahlen, 1897, i, p. 14.
† Phila. Med. Jour., 1901, viii. p. 404.
‡ N. Y. State Jour. of Med., 1902, ii, p. 176.
§ "Krebs und Röntgenstrahlen." Haarlem, 1902.
‖ American Medicine, 1902, iv, p. 217.
** Med. Record, 1902, lxi, pp. 361, 801.
†† Kan. City Med. Index-Lancet, 1902, xxiii, p. 18.
‡‡ Brit. Med. Jour., 1901, i, p. 1398.
§§ Southern Califor. Practitioner, 1902, xvii, p. 140.
‖‖ "The Röntgen Rays in Medicine and Surgery," p. 670.

Ferguson * reports an inoperable recurrent scirrhous growth the size of a hen's egg on the manubrium of the sternum, for which he advised the use of the Röntgen rays. They were applied for twenty minutes on as many days. After a month's absence the patient returned in excellent health and spirits. The sternal growth had completely disappeared, the ulcerated surface below the growth had healed, and the pain—considerable before—had greatly lessened, being confined to the arm alone, the swelling of which had diminished. There was still some deposit around the axillary vein.

Soiland has reported the case of a woman with a carcinomatous ulcer the size of a dollar on the left breast with indurated nodules around it. After six weeks of exposures every other day all external manifestations disappeared; the ulcer healed, the skin over the gland became movable, there was no pain, and the general health of the patient was improved. There were still a few hard nodules in the gland.

Ayers has reported two cases of mammary carcinoma treated by this method. In the first case evidence of recurrence was seen before healing of the wound after operation. At the beginning of treatment there was an indurated mass two inches below the scar. This case was given exposures of four minutes daily for three and a half months, at the end of which time all induration had disappeared. The cicatrix was normal, the skin soft and flexible, and there was no pain. In the second case the tissues of the upper half of the left side of the chest were indurated and immovable, with three ulcers, each the size of a lemon, and there was a large indurated mass in the axilla. There had been several hemorrhages from the surface. As result of treatment there has been marked improvement. The tissues are much softer and more movable, the nodules are shrunken, and the mass is reduced to one-third its previous size.

Andrew Clark has made a preliminary report upon an interesting case treated by this method. The patient, a woman aged sixty, had been in Middlesex Hospital in 1894 for a tumor of the breast which had been recognized as carcinoma and for which operation had been advised and declined. She was again in the

* Brit. Med. Jour., 1902, i, p. 265.

hospital in 1898. In 1901 the tumor had enlarged and ulcerated and become very painful, so that she sought readmission to the hospital. The induration and ulceration had extended gradually. On March 6, 1901, at the suggestion of Mr. Clifford, the house surgeon, *x*-ray exposures were begun, and the exposures had been continued five days a week for nine weeks at the time of the report. On March 9 there was a note: "Breast a little cleaner, numerous islands of epithelium present." April 14: "Appearance of breast still improving; much less pain." April 23: "Still free improvement in the ulceration and diminution in the size of the indurated lump." On May 14 the induration had become much less and the patient had little pain. The glands in the axilla were smaller and her general condition improved.

C. W. Allen has reported one case of recurrent carcinoma of the breast with nodules in the other breast which is "practically well." He also reports improvement in five other cases of recurrent carcinoma of the breast. Eijkman has reported one case of carcinoma of the breast, with involvement of the axilla, in which almost all evidence of disease has disappeared. Morton has reported one case of carcinoma of the breast symptomatically cured, and three others improved.

On the other hand, Johnson and Merrill have reported four cases of mammary carcinoma treated by this method, none of which were improved.

I have treated 25 successive cases of carcinoma of the breast in which the results allow some opinion to be formed as to the efficiency of the treatment. Of these, 18 cases were recurrent carcinoma of the breast, and 7 cases were primary carcinoma of the breast. I have also given *x*-ray exposures to 14 cases as a prophylactic measure after operations for carcinoma of the breast and before any evidence of recurrence had appeared.

Recurrent Carcinoma of Breast.—*Case* 74.—Mrs. ———, aged thirty-eight. A very extensive recurrent carcinoma of the breast with involvement of axilla which had been passed upon as inoperable by Dr. Charles McBurney, of New York. This was the first case of the sort that I attempted to treat and was early in the history of the method, and the chances of benefit

seemed so infinitesimal that with my concurrence the treatment was discontinued after five weeks. There was no positive benefit.

Case 75.—Mrs. ———, aged forty-eight, referred to me on July 18, 1901, with the following history: Six years ago she had an operation by Prof. E. C. Dudley, of Northwestern University, for laceration of the cervix, and her general health had been bad for several years with complete nervous breakdown but without demonstrable lesion. The family and personal history contains no salient facts. In 1899 a tumor developed in her right breast, which was recognized as a carcinoma, and in April, 1900, was removed. Recurrence became evident in the scar six months after removal, in the fall of 1900. In the spring of 1901 she was seen by Prof. Christian Fenger, of Rush Medical College, and the case pronounced inoperable. The condition when she came to me eight months after recurrence is shown in the accompanying photograph (Fig. 152). On the right side of the chest between the site of the nipple and the axilla was a dense, hard, nodular mass six inches in diameter attached to the ribs. The cicatrix was star-shaped and the center of it was a mass of closely grouped waxy nodules which were ulcerating. In the axilla was a mass of indurated scar tissue, but no glands were palpable there. The arm, however, was enormously swollen and tense down to the very fingers. There were no glands palpable in the supraclavicular region. She was suffering very severe pain, for which morphin was necessary.

The case was put under daily exposures at 5 cm. distance and of fifteen minutes' duration, July 18, 1901, and by August 13, after twenty exposures, a marked dermatitis had been caused over the entire area, and a bulla had formed over the center of the mass. The treatment had been as vigorous as I dared, because it seemed evident that if anything was to be done it had to be done quickly. This effect disappeared by September 2, when the entire surface was healed over and the discharge ceased. At the same time there was a very marked shrinkage of the nodules and disappearance of the œdema of the arm. With the exception of an interval of six weeks, when

the patient had an acute illness not connected with her carcinoma, she had vigorous exposures almost daily from September 2 to December 4—thirty-one in all. An acute dermatitis was again set up in the latter part of October, but after that date the exposures were never carried to the point of producing an acute reaction. On November 8 I made the following note: "The dermatitis has entirely disappeared, the skin is of normal color except for pigmentation around the periphery of the exposed area. The skin where the tumor existed is smooth, and it is impossible at present to find any evidence of carcinoma in the area. All of the nodules have entirely disappeared." The condition at that time is shown in figure 153, for which I am indebted to an amateur photographer.

From December 1, 1901, to May 1, 1902, this patient received several series of irregular exposures without at any time showing marked reaction. From May 1 to November 1, 1902, there were practically no exposures. The condition of the arm and the condition of the chest-wall still remains to date [December 1, 1902] as satisfactory as it was in November, 1901, with the exception that in November, 1902, two small nodules the size of a split pea developed at the center of the cicatrix.

This patient's general condition was bad at the beginning of treatment and it remains bad at the present time. In the spring of 1901 we were very much afraid of pelvic carcinoma. Our fears in that direction proved groundless, but at present there are pressure symptoms referable to the lower part of the cord, due probably to beginning metastasis in the lumbar vertebræ.

The disappearance of the œdema of the arm in this case is, of course, a most instructive fact. When it occurred it gave evidence, much needed at that time, of the deep effect of *x*-rays.

Case 76.—The following report of this case was made February, 1902: Mrs. ———, aged fifty-eight, referred to me by Dr. C. C. Gratiot, of Shullsburg, Wis. The patient was in Dr. Christian Fenger's care in Passavant Hospital in July and August, 1900, and the following facts are taken from the hospital record, which Dr. Fenger kindly placed at my disposal: "Her present [July, 1900] trouble began about six years ago, when

Fig. 152.—Recurrent carcinoma of the breast.

Fig. 153.

patient noticed a little hard lump on the inferior aspect of the left breast on the axillary side. There was a scarcely perceptible enlargement of the hard area until about two years ago, when the patient noticed a more rapid enlargement. She then consulted Dr. Sheldon, of Madison, Wis. At that time this growth developed very fast and broke through the skin and formed an open sore, which grew in dimensions until it is now the size of a silver dollar. Dr. Sheldon advised an operation, whereupon she consulted Dr. Fenger." Dr. Fenger removed the breast with the axillary and supraclavicular glands in July, 1900. A few months after removal the disease reappeared in the scar. She returned to Dr. Fenger last summer, but he found the case beyond operation. Her condition when she came to me, November 1, 1901, is shown in the accompanying photograph (Fig. 154). As seen in the illustration, there was a mass of carcinomatous tissue on the left side involving an area of about a square foot. The nodules varied from the size of a hazelnut to that of a small apple. At the upper inner angle there were a couple of ulcers 2½ to 3 inches in diameter. Around the main mass, and separated from it by distances of from two to three inches or more, were numerous hazelnut-sized nodules. She had on two occasions suffered alarming hemorrhage from the surface. Dr. Fenger had thoroughly removed the glands in the axilla and above the clavicle, and no enlarged glands in either of these locations were found. When she began treatment, she was suffering a great deal of pain. She was so weak that a nurse had to bring her by easy stages from the nearest hotel for her treatments, and she was in every way thoroughly haggard and worn.

She was put under *x*-ray exposures on November 1, and the sittings were given daily for two months, and every other day or less frequently after that. Two weeks after the treatments were begun she volunteered the statement that her pain was gone, and she has had none since. On January 17 I made the following note: "There has been rapid subsidence of the tumor for the last month. The improvement can be seen from week to week. There is at present only a slight superficial ulceration about the size of a dime at one point and one small

nodule the size of a pea. The surface is free from infiltration and thickening and the redness has almost disappeared. The skin is considerably pigmented." (Fig. 155.) Improvement has continued since that time. The condition February 27, 1902, is indicated in the accompanying photograph (Fig. 156). There is no evidence of carcinoma left on the chest-wall. There is a thin, soft, brownish-white scar, which is almost freely movable. Around the borders of the scar there are numerous dilated capillaries, the remnants of the previous abundant vascular supply of the tumor. It seems hardly credible that this scar represents the site of the previous tumor mass.

Her general condition has progressed equally well. As I said above, she has been free from pain since ten days after treatment was begun. Since January 1, 1902, she has been strong enough to come in alone three times a week for her treatments from a town thirty-five miles from Chicago. She has regained her appetite and has increased in flesh decidedly (10 to 15 pounds). Now she presents the picture of a healthy old lady.

The first series of treatments in this case were ended in the middle of February, 1902, and the patient was sent home to return in three months. In May, 1902, she returned, and at that time the scar on the anterior chest-wall remained smooth and clean, but in the posterior axillary line three inches below the axilla there were five or six pea-sized nodules and in the right axillary space there was a filbert-sized, movable, hard gland. Her general condition was excellent. She had previously suffered from a hacking cough, which bothered her no longer. During May and June, 1902, she had rather vigorous exposures, with the production of an acute dermatitis, which disappeared slowly, and with it all of the nodules. The gland in the right axilla also disappeared under exposures.

This was the first time that this patient had had an acute dermatitis. The previous lesions were removed without producing more than a very slight dermatitis, but with marked pigmentation. From the middle of June until the middle of September, 1902, she had no treatment. When she returned in the middle of September, there was a patch in the anterior axillary line on the left side, formed by the coalescence of

Fig. 154.—Recurrent carcinoma of the breast, November 1, 1901.

Fig. 155.—Same case as 154. Condition January 20, 1902.

Fig. 156.—February 25, 1902.

several flat nodules from the size of a dime down. All these nodules were hard, dark red, and not tender. There were two very small glands palpable on the left side of the neck, none on the right. There was a gland in the anterior part of the right axilla the size of a dime, and a small gland about an inch and a half below it in line with the nipple. She was having slight pain, but not enough to particularly interfere with her comfort, and her general condition was good. From September 13 to October 6, 1902, she had vigorous exposures, with the production of an acute dermatitis, upon the occurrence of which the lesions disappeared in all of the locations. December 15, 1902, she remains in good condition, without evidence of carcinoma.

As may be seen, there have been two minor recurrences in this case, and of course it could not be said that the patient is in any way relieved from the prospect of further recurrences. But the course of the case under *x*-rays has been of a character that has been totally unknown in such cases previously. This patient in November, 1901, was in a condition where death was inevitable in the course of a very short time. She had been suffering harassing pain for months, had had two alarming hemorrhages from the mass, and from pain and anxiety and loss of blood she was reduced in strength to a marked degree. Her physical vigor has been restored, she has been kept free from pain, and she has been relieved from practically all manifestation of carcinoma for a year. This case tends to disprove the idea which has been suggested, that after a certain amount of exposure carcinomatous tissue is no longer susceptible to the influence of *x*-rays. It has certainly been as easy to get rid of the second and third recurrences as of the first.

Case 77.—Miss ———, aged forty-nine, referred to me by Dr. A. J. Ochsner. In February, 1899, she noticed a hard lump in the left breast, which was followed by gradual retraction of the nipple. In February, 1900, the breast was removed by a well-known surgeon, but the disease soon recurred in the scar, and in October, 1900, a second operation was done. A second recurrence soon showed itself, whereupon she consulted Dr. Ochsner, and on November 25, 1901, he referred her to

me. When she began treatment with *x*-rays there were two ulcers about the middle of the scar, each the size of a twenty-five-cent-piece, surrounded by purplish-red indurated tissue. The case was given moderate *x*-ray exposures from November 25, 1901, to January 27, 1902, when considerable erythema developed and the exposures were stopped for two weeks. With the disappearance of the dermatitis the ulcers rapidly grew smaller, and by January 20 had been replaced by soft, healthy scar tissue. After the disappearance of all evidence of disease the exposures were still given during February, March, April, May, and June, part of the time over the chest, part of the time in the axilla, and part of the time over the supraclavicular region, and she had similar exposures again during October and November. During this time it was the aim to keep the reaction below the point of producing a dermatitis, but very marked pigmentation was produced. There has never been any evidence of recurrence of the disease on the affected side.

In May, 1902, a small, hard, disc-shaped mass was discovered beneath the nipple in this patient's right breast, and she was immediately put under *x*-ray exposures over this area and the corresponding supraclavicular and axillary areas. The exposures were carried to the point of producing an erythema which became a bright dry dermatitis and then subsided. With the subsidence of this by the middle of July the mass entirely disappeared. This patient was examined by Dr. Ochsner November 1 last, a year after beginning treatment, and he wrote me: "It seems to me that Miss ——— is entirely well."

This case represents the type of recurrent carcinoma of the breast which shows the best results from the use of *x*-rays. The patient had had a primary operation and one operation for recurrence, and a vigorous second recurrence had begun. Every one knows how hopeless it is to attempt further surgical intervention in cases of this character. Further operations offer practically no hope of success, even when there is enough tissue left on the chest-wall to make an operation feasible. In the ordinary course of events nothing except the early death of the patient was to be expected. In this case the patient is well a year after beginning treatment, she is in vigorous health,

and throughout the time of her treatment she has been able to pursue an exacting occupation.

Case 78.—Mrs. ———, aged forty-one, referred to me by Prof. A. J. Ochsner, of the University of Illinois. In November, 1901, Dr. Ochsner removed a carcinoma of the breast and enlarged glands in the axilla, and one enlarged gland high up under the subclavian vein. The case was referred to me for prophylactic treatment of the scar on the left side and for treatment of the condition of the right nipple, which had been diagnosticated as Paget's disease. The disease in the left breast had been preceded by a similar affection of the nipple. At the time she came to me there was a healthy scar on the left side. The right breast showed no induration except beneath the nipple, but the areola and nipple were involved in a chronic dermatitis of several years' duration. The areola was red, covered with scales and crusts, and the nipple had almost disappeared, and there was a thick disc of indurated tissue beneath the areola.

This patient had between November, 1901, and October, 1902, several series of exposures over the right side as a prophylactic. She was given twenty-two exposures over the diseased nipple between January 7 and March 7, 1902, with the production of a slight erythema. By March 7 the nipple was entirely well, the induration was gone, and it has remained well since that time. The malignant character of these carcinomata beginning in the areola of the breast, which were first described by Sir James Paget, is well known, as is their intractability to all treatment except excision. This, I believe, is the first case of Paget's disease thus treated that has been reported.

Case 79.—Mrs. ———, aged seventy-eight, referred to me by Dr. Christian Fenger, of Chicago, and Dr. Carl E. Black, of Jacksonville, Ill. Eight years ago a tumor developed in the left breast, which was removed by operation, and subsequently two other operations were done. Dr. Fenger and Dr. Black advised against further operation, and in February, 1902, referred her to me. At that time there was a hard mass of glands in the axilla and under the border of the pectoral muscle. The supraclavicular space was swollen and contained a hard

gland almost as large as an olive. The forearm and hand were swollen and œdematous, and the arm was considerably larger than the other arm, but was only slightly œdematous, the enlargement being due to connective-tissue hyperplasia from long-continued lymphatic obstruction rather than to œdema. She was run down physically and had a cough. *X*-ray exposures of moderate intensity were begun over the pectoral area and the axillary and supraclavicular spaces, and were continued until March 29,—twenty-five exposures in all,—with the production of a moderate dry dermatitis and a good deal of pigmentation. At that time the swelling in the forearm and hand had almost entirely disappeared. On April 16 she returned for further exposures, the dermatitis having subsided. There was free improvement in all of the involved areas.

She had twelve exposures between April 16 and May 12 and no further exposures until August 1. During the second series of exposures there was a very marked pigmentation produced, but no dermatitis. The improvement in the local condition and in the patient's general health was continuous. By May 12 the masses in the border of the pectoral muscle and in the axilla were very much smaller and softer and the supraclavicular gland was soft, though still palpable. The patient was feeling well and vigorous, had no pain, and altogether there was a very marked improvement in her condition; this in spite of the fact that she had spent the months of March and April in the inclement weather of Chicago, which was unusual for her, and had exposed herself to the weather very much more than was her previous custom.

When she returned, August 1, for further treatment, the improvement had continued. There was no evidence of recurrence of the growth and her general health was still good. Between August 1 and September 12 she received 30 exposures, without the production of any reaction except a marked pigmentation. Since that time she has had no treatments. At the end of this series of exposures the condition remained good. The entire affected area was free from induration, the axilla soft, and the gland above the clavicle as soft as adipose tissue and almost impalpable.

Case 80.—Mrs. ———, aged forty-six, referred to me by Dr. G. H. Brannon, of Manhattan, Ill. For many years she had a lump in the left breast, which last year began to increase in size, and in September, 1901, was removed. There was some recurrence in the scar, and this was removed by operation a month before she came to me. At the time that she was referred to me, April 28, 1902, there was a healthy looking scar attached to the ribs, but in the axilla was a large mass of dense, hard, indurated glands, and above the clavicle a mass of hard glands was palpable. The arm and forearm were slightly œdematous. The patient's general health was very markedly run down. The condition of this patient at the time of coming under treatment was as closely similar as possible to that in the preceding case. The course of the cases under *x*-rays has also been identical. This patient has had more or less regular exposures from May 28, 1902, to date, having had 78 exposures of fair intensity between April 28 and November 10. In this case the reaction has never gone beyond the production of a moderate erythema. A condition of considerable pigmentation has been maintained almost throughout. The improvement in the patient has been continuous, until there is now no evidence of carcinoma. The only evidence of disease above the clavicle is a soft gland. The condition of the patient's general health has improved correspondingly. She is now well and vigorous and able to attend to her ordinary household duties. At the beginning she was just able to drag herself about.

Neither this case nor the one preceding can, of course, as yet be claimed as more than symptomatically relieved, and both are to continue treatment, but the results in both cases may be regarded, I believe, as highly satisfactory. These were both cases of the type of slow-growing carcinomata that gradually wear the patient out and that are totally unamenable to surgical intervention. Case 79 would probably have lasted for some time; Case 80 had every prospect of being worn out in a very short time.

Case 81.—Mrs. ———, aged forty-six, referred to me by Dr. Kossuth Tinker, of Athens, Ohio. In May, 1901, the left breast was removed for carcinoma of a few months' duration,

and the wound remained healthy until April, 1902. At that time she discovered several superficial nodules developing in the subcutaneous tissue of the chest-wall along the line of the scar. At the time she came to me there was a healthy looking scar except for a half-dozen nodules the size of a large marrow-fat pea and smaller. These were indurated and purplish in color, and unquestionably carcinomatous. The axilla and supraclavicular areas showed no induration, but the arm was swollen and there was a good deal of pain in the shoulder. She had eighty-two exposures between May 27 and October 7, with the production of slight erythema on several occasions, and toward the last of an acute dermatitis. Under the treatment the nodules gradually diminished in size and three months after beginning treatment had entirely disappeared.

Case 82.—Mrs. ———, aged fifty-eight, referred to me by Dr. W. B. Young, of Bonair, Tenn. In the summer of 1901 a small lump which had been in the right breast for many years began to increase in size, and in November, when it had attained the size of a fist, was removed by Dr. Young. Early in January, 1902, the disease recurred in the scar, and after that time spread rapidly and was accompanied by severe darting pains. At the time she came to me, May 1, 1902, there was a large mass about the scar on the right side of the chest, the induration extending from the border of the left breast to the posterior axillary line and from the third to seventh ribs in nipple line. The mass was of a brownish-red color, dotted with hard reddish nodules the size of large peas. In the center of the area there was an ulcer as large as a silver quarter. No glands were palpable in the axilla, but the tissues were indurated and brawny.

She was put under *x*-ray exposures and received, between May 1 and September 11, ninety-four exposures, with the production on several occasions of a rather acute dermatitis, which always subsided promptly. The almost immediate effect of the treatment was to stop the pain and there was rapid improvement in the breast. On June 4, one month after beginning treatment, the ulcer had healed, but there still remained indurated nodules. These rapidly disappeared until by the

middle of June the area was entirely free from suspicious points. The scar was then soft and movable.

In June a suspicious disc-shaped mass was discovered in the upper part of the left breast which was removed by a radical operation in September.

Case 83.—Mrs. ———, aged fifty. Six years ago she detected a mass in the left breast and retraction of the nipple, and the breast was subsequently destroyed by several series of treatments with caustics. Two years ago a similar condition developed on the right side, and in July, 1900, this was removed with caustics. In December, 1900, the patient detected in the scars evidence of recurrence which had increased up to the time she was referred to me. The condition when she came to me is shown in figure 157. The scar on the left side was healthy looking except for three hazelnut-sized nodules. On the right side the scar was indurated and brawny and at the center there was an irregular indurated ulcer 2½ by 1 inches. There was no evidence of involvement of either axilla. Between May 28 and July 14 the patient received almost daily exposures of moderate intensity. On July 18 an acute vesicular dermatitis was produced, and the exposures were discontinud until August 6. In the mean time the dermatitis subsided, and with its disappearance all evidence of the disease vanished. When she returned for treatment on August 6, all nodules had disappeared and both scars were markedly more movable than before, and the feeling of contraction in the chest-wall, which had been a source of discomfort and annoyance to the patient, was very greatly improved. The condition since that time is shown in figure 158.

The following cases are all cases in which practically a failure occurred.

Case 84.—Mrs. ———, aged fifty. In 1898 a thorough removal of the breast was done by Dr. A. J. Ochsner, and the scar remained healthy until a few months before coming to me, when an ulcer began at the nipple site. At the time of beginning treatment there was a thick mass of carcinomatous tissue on the chest-wall, closely adherent to the ribs, with a gangrenous slough at the center as big as a silver quarter.

The supraclavicular glands were markedly involved. Vigorous treatment for three months had no apparent effect, and the patient died suddenly as a result of involvement of the lung.

Case 85.—Mrs. ———, aged fifty-two, referred to me by Dr. Grey, of Chicago. A year ago the left breast was removed by radical operation for carcinoma. There was a prompt recurrence, and when she came to me on June 18, 1902, there were a number of nodules along the line of the scar. The tissue along the border of the pectoral muscle was hard and indurated. There was a hard mass of nodules in the left axilla and the entire left arm was intensely œdematous. There was a hard mass above the clavicle. The patient was suffering much pain and was very greatly reduced in health. Treatment in this case was continued from June 18 to September 13, with very considerable relief of pain, and with almost entire disappearance of the œdema, but there was no other improvement. The patient's general condition grew steadily worse until treatment was discontinued.

Case 86.—Miss ———, aged fifty-two, referred to me by Dr. H. R. Chislett, of Chicago, February 5, 1902. A year before a radical operation had been done for carcinoma of the right breast. When she came to me, there was a healthy looking scar from the axilla to the median line. The scar in the axilla was indurated and several hard glands were palpable in the axilla and there were two large hard glands above the clavicle. In the left axilla there was a mass about the size of an olive. The right arm was œdematous. The patient was running down rapidly and was suffering a good deal of pain. This patient had vigorous exposures for most of the time between the middle of February and the middle of June, 1902. The pain was relieved to a considerable extent and the glands in the axilla and supraclavicular region were reduced and made softer, but there was no other effect in the case, and the patient went from bad to worse until the treatments were discontinued.

Case 87.—Mrs. ———, aged fifty-four, with a very extensive ulcerating recurrent carcinoma of the left breast and involvement of the axillary and supraclavicular contents. She had vigorous exposures for a month without any practical effect except relief

Fig. 157.—Recurrent carcinoma after removal of both breasts with caustics.

Fig. 158.

of pain, drying up of discharge, and disappearance of odor, and she suddenly died, a month after beginning treatment, from involvement of the lung.

Case 88.—Man, aged fifty-five, referred to me by Prof. D. A. K. Steele, of the University of Illinois. A year before a carcinoma of the right breast had been removed by radical operation. At the time of coming to me there were several hard nodules, the size of a hazelnut and smaller, along the line of the scar, and in the axilla there were several indurated glands. There was a good deal of pain. Under fairly vigorous *x*-ray exposures,—thirty-three in all,—in May and June, 1902, the nodules all disappeared from the scar and the glands in the axilla became soft and hardly palpable and his pain was relieved. The improvement was so great that in July he thought himself cured, and against my advice quit treatment. November 1, 1902, he died; doubtless of metastatic carcinoma, although I have not the details.

Case 89.—Mrs. ———, aged fifty. A carcinoma of the left breast was removed in March, 1900, by radical operation, and a recurrence in the supraclavicular glands and chest-wall was removed by a second operation six months later. When she came to me on January 18, 1902, there was a *cancer en cuirasse* involving the entire left chest-wall. All of the tissue was bound down and the movement of the chest impeded. The axilla contained a dense mass of indurated glands and a similar immovable mass existed behind the clavicle. The arm was markedly œdematous; she was much reduced in health and was suffering much pain. Twenty-seven vigorous *x*-ray exposures in January, February, and March, 1902, had no effect except the relief of pain.

Case 90.—Mrs. ———, aged sixty-eight. November, 1900, a tumor of the breast was removed by Dr. C. Fenger, and she first noticed a recurrence in the scar in January, 1902. It grew rapidly and soon ulcerated, and was very painful. When she was referred to me, May 7, 1902, there was a dense mass of carcinomatous tissue occupying the entire right side of the chest from the left border of the sternum to the posterior axillary line. At the center it was thrown up into a hard nodular

mass with a gangrenous ulcer in the center an inch in diameter. Treatment for a month and a half had no effect in this case and the patient quit.

Case 91.—Mrs. ———, aged seventy, with a *cancer en cuirasse* involving the entire left side of the chest. This had begun many years ago as a tumor in the breast and increased slowly until a year ago, since which time it has spread rapidly. When she came under my care, January 20, 1902, the entire left chest-wall was covered with a brawny, hard, purplish inelastic mass, which rendered that side of the chest almost immovable. The induration from the left side reached beyond the median line in front and there was a hard nodular mass in the right breast. The axillary and supraclavicular spaces were involved and the left arm was enormously swollen. She was not suffering much pain, but suffered great distress from interference with breathing. She had twenty-one vigorous *x*-ray exposures between January 20 and February 20, 1902, with no apparent effect. She died within a month after discontinuance of treatment.

Summary.—In the above list of eighteen cases, eight cases, or 44.4 per cent. (Cases 74, 84, 85, 86, 87, 89, 90, and 91), showed practically no result except in most instances marked relief from pain. In all of those eight cases there was involvement of the supraclavicular glands at the beginning of treatment and probably intrathoracic metastasis as well. One patient (Case 88) was relieved of the evidence of carcinoma locally, but died soon after, presumably from metastasis.

The remaining nine cases, or 50 per cent., show results that in my opinion may be regarded as satisfactory. One of these cases (Case 75) has shown almost no recurrence at the original site of the disease, but perhaps has carcinoma of the spine. In another (Case 82) carcinoma developed in the other breast, which was removed by operation. Another case (Case 76) showed two slight easily handled recurrences, but the patient, from a condition of helpless invalidism, has been restored for a year to fair health. In Case 79 the patient is not relieved of all trace of carcinoma, in that soft glands are still palpable, but has been restored to good health and the disease has shown no tendency to revive. In the remaining five cases (Cases 77,

78, 80, 81, 83) there is symptomatic cure. In one case (Case 78) there is cure of the carcinoma treated by *x*-rays (Paget's disease), but it is by no means certain that this patient will not have a recurrence of the carcinoma of the other breast, which was removed surgically. In four cases (Cases 77, 80, 81, and 83) there is symptomatic cure and the condition is all that could possibly be hoped for.

The failures in this series of cases may readily be admitted and still the method of treatment be amply justified by the results. It is surely true that in such cases as these there will never be any method that will not have its failures. A more unpromising group of cases could hardly be imagined. Every one of them was practically beyond relief by any other method. Most of them had been refused further operative procedures and had no outlook left except pain and misery and a hopeless illness. If in the whole group only one case existed showing such results as are seen in Cases 76, 77, or 80, for example, the method would seem to have ample justification for its use. That practically 50 per cent. of the cases have had relief seems as good a showing as could possibly be expected. The cases indicate one thing strongly, and that is the extreme importance of getting the patients for treatment at the first evidence of recurrence. It is then that there is a fair chance of getting them well. If the disease is allowed to go on until the glands behind the clavicle and within the thorax are involved, the chances for relief are very much reduced.

Primary Carcinoma of the Breast.—*Case* 92.—Miss ———, aged forty-five, referred to me by Dr. Wm. J. Mayo, of Rochester, Minn. In 1900 her attention was called by sharp pains in that region to a small hard mass in her left breast. Since that time the tumor has been growing steadily, but she has had only infrequent pains. Otherwise she has been in good condition. At the time she was referred to me there was a hard nodular mass an inch and a half in diameter in the left breast, movable and not tender. The nipple was retracted. No glands were palpable in the left axilla. This patient has been under treatment at intervals since April 8, 1902. Up to August 18 she had ninety exposures, and she then had no further exposures until November

6, 1902. After beginning the treatment the breast became considerably larger. On August 5 the following note was made: "Since last examination of breast, July 31, there has been a notable decrease in the size of the tumor, which is now about two-thirds of its original size." August 19: "Considerable erythema over breast. Patient says the breast feels quite sore and tender." On August 22 she was allowed to go home, as there was an acute vesicular dermatitis, and she did not return until November 6. At the time of her return the retraction of the nipple had almost disappeared and the tumor was not more than one-third its original size. The mass in the breast is hard and movable and of regular outline, like a mass of fibrous tissue rather than a carcinoma. The patient's general condition is considerably improved.

Case 93.—Mrs. ———, aged seventy-six, referred to me by Dr. A. J. Ochsner. At the time she came to me, June, 1901, there was a tumor the size of an orange in the upper and outer quadrant of the left breast. This was very hard, somewhat nodular, adherent to the skin, and only slightly movable. Several glands were palpable in the axilla. This patient had vigorous exposures in July and August, 1901, with the production of an acute dermatitis. The pain, which was severe at the beginning, was entirely relieved, and by the latter part of August the tumor was certainly softer and somewhat smaller; but the patient quit treatment, and I have not been able to get trace of her since.

Case 94.—Mrs. ———, aged sixty-six, referred to me by Dr. Kearsley, of Chicago. In the right breast there was a hard disc-shaped movable mass under the skin two inches in diameter. The patient had had occasional shooting pains in the right breast for three months, but the mass had been noticed first a few weeks before. The nipple was completely retracted. There were a number of hard glands the size of a lima-bean in the right axilla. The patient was nervous and suffering from lassitude and weakness. This patient has had persistent treatment, except at times when there has been dermatitis, from May 5 to date, having had up to November 10 one hundred and forty-nine exposures. At the present time the mass in the

breast is about two-thirds the size that it was at the beginning of treatment. The glands in the axilla are soft and have hardly been palpable since the middle of August.

Case 95.—Mrs. ———, aged forty-five. Four years ago a small lump was noticed in the right breast, which gradually enlarged to its present size. During the last year it enlarged more rapidly and she had frequent shooting pains. When referred to me, there was a large, hard, nodular, egg-sized mass in the right breast and retraction of the nipple. No glands are palpable in the axilla. This patient had vigorous exposures from January 1, 1902, to May 9, 1902,—eighty-four in all,—with the production at the last of an acute weeping dermatitis. This persisted for several weeks, during which time there was rapid decrease in the size of the tumor. Since August 1 she reports the breast has been apparently normal; the mass has disappeared, the breast is soft, free from pain or tenderness, and the nipple not retracted.

Case 96.—Miss ———, aged forty-one, referred to me by Dr. Y. H. Bond, of St. Louis. At the time of coming to me, December 12, 1901, there was an indurated mass in the left breast—hard, freely movable, irregular in outline, and about two inches in diameter. There was a similar but smaller mass in the right breast, somewhat more superficial, nodular and movable. There were no glands palpable in the axillæ. The nipples were not retracted. Her attention was first called to her breasts in March, 1901, by the fact that at times there were dull aching pains in either breast. She then discovered the masses, which she thinks have increased slightly in size since that time. She had vigorous *x*-ray exposures during December, 1901, and January and February, 1902. The exposures were discontinued on account of dermatitis the first of March. After stopping treatment the dermatitis was quite severe for two months. When she returned, August 27, 1902, the skin was still somewhat red. During September and October she had further exposures, with the production of a second dermatitis, on account of which treatment was discontinued. The result in this case is about the same as in Case 92. There is considerable diminution in the size of the tumors, but they have not disappeared.

Case 97.—Mrs. ———, aged sixty-five, referred to me by Prof. E. Wyllys Andrews, of Northwestern University, January 17, 1902. When treatment was begun, she had an indurated immovable carcinoma involving the entire right breast and axillary glands and the supraclavicular glands. There was also metastasis in the spine and probably at other points, and she was suffering great pain. The treatments were given with the hope of relieving pain without any expectation of influencing the course of the disease. She had vigorous exposures for four weeks, and after that irregular exposures up to the time of her death, two months after beginning treatment. A dermatitis was produced over the breast at the end of three weeks. The relief of pain was prompt and marked, and continued to the end.

With the production of the dermatitis over the breast and in the axilla there was a rapid disappearance of the induration. The breast became soft and the evidence of carcinoma entirely disappeared in that location. A post-mortem examination was made by Dr. J. J. Larkin, who reported upon the case to Dr. Andrews as follows: "The tumor of the breast had nearly all disappeared; skin that had been burned by the rays was entirely restored. The enlarged glands under the arm of the affected side had reduced to one-third of their former size."

Case 98.—Mrs. ———, aged sixty, referred to me by Dr. J. B. Murphy and Dr. F. S. Hartman, May 12, 1902. She had noticed a growth in the breast five years ago, which gradually increased, and during the last year grew rapidly. At the time she was referred to me there was in the right breast a large hard mass which was adherent to the skin. There was a puckered retraction at the site of the nipple. Indurated glands in the axilla were palpable. She had recently had an acute gastric trouble, but at the time of coming to me had recovered. This case was given vigorous exposures from May 12 to July 17, and a slight dermatitis was produced. On July 8 I made the memorandum: "The mass in the breast is certainly smaller." July 20 she was taken with an acute illness and I did not see her again. On August 20 Dr. J. B. Murphy wrote me as follows: "I saw Mrs. ——— on last Friday. The carcinoma of the

breast has entirely disappeared, but she is suffering from a gastric disturbance from which I fear she will die." She died a short time afterward and the breast was obtained for examination. Prof. W. A. Evans, of the University of Illinois, examined it and informed me that the tumor had been converted into a small fibrous mass about the diameter and about two-thirds the length of an index-finger. It was a hard mass of fibrous tissue. Microscopically it consisted of heavy fibrous tissue bands with a few islets of epithelium, some of the epithelium being in a fair state of preservation, but most of it in a state of advanced retrogressive change. There were several axillary glands remaining, about one centimeter in diameter, the epithelium of which was in a fair state of vitality. The mass in the breast was practically scar tissue. The epithelium undergoing retrogressive changes showed the same characteristics that I have described in my sections and that other observers have described. What the trouble was that caused her death Dr. Murphy and Dr. Hartman were not able to determine before death, and post mortem only a partial examination of the abdomen was permitted. The abdomen was opened and a superficial examination disclosed no carcinoma. The patient died from a rather acute gastric disturbance lasting about six weeks, in which the most important symptom was persistent vomiting. The symptoms seemed to point to an intestinal obstruction or to nephritis, but the character of her final illness was not definitely determined.

These two cases are, of course, instructive in that they show conclusively the effect of *x*-rays upon carcinomatous tissue in the breast.

Summary.—This group of seven cases of primary carcinoma of the breast is, of course, too small and the time that has elapsed too short to admit of deductions. In one of the cases (Case 95) there has been a symptomatic cure. In the only two of the patients that have died (Cases 97 and 98) the masses had become impalpable and showed only a small mass of fibrous tissue post mortem. In these three cases surgery could have done no more than *x*-rays did. In three of the cases (Cases 92, 94, and 96) the disease has been checked. In one (Case

93) there was no result; the patient quit after inadequate treatment and I have been unable to trace her. Five of the seven cases were referred to me by surgeons and presented highly unfavorable prospects of successful surgical removal. It may be added that the other two, one of which has been symptomatically cured, had declined operation.

In the present state of our experience with *x*-rays in carcinoma of the breast I believe the safe position is to advise operation in suitable primary cases, and I have persistently refused to take such cases for *x*-ray treatment except where they have been referred to me by men whose judgment as to the question of operation was good, or where the physician in charge assured me that the patient had unequivocally declined operation.

I have treated two nondescript cases of tumor of the breast in nervous women.

Case 99.—Mrs. ———, aged thirty-one, referred to me by Dr. A. J. Ochsner, March 7, 1902. She had noticed for some time lumps in either breast. At the time she came to me there was a mass in the left breast the size of a walnut, not very hard, freely movable, and somewhat tender. There was a similar but smaller mass in the right breast. There were two enlarged, not very hard glands in the left axilla. She complained of a good deal of pain in either breast. She was given twenty-five exposures of moderate intensity between March 7 and July 26, with the production after stopping treatment of an acute dermatitis. The pain disappeared soon after beginning treatment, and four weeks after stopping treatment the indurations in the breast had entirely disappeared. Since August 1, 1902, both breasts have been free from induration or pain. The axillary glands disappeared under similar exposures.

Case 100.—Mrs. ———, aged forty. At the time she was referred to me, July 29, 1902, there was below the nipple in the left breast a disc-shaped mass about an inch in diameter. It was quite superficial but was not attached to the skin; was not very hard and was tender. Her attention was first called to it a short time before by shooting pains. There were no

glands palpable in the axilla. She had between July 29 and October 2 twenty-seven exposures of moderate intensity. By August 22 the mass was markedly smaller and the shooting pains had disappeared. By September 25 the mass in the breast was gone.

Both of these cases were symptomatically cured. Both of them may have been carcinomata, but there is enough uncertainty as to their character to warrant their rejection from any list of carcinomata.

Mediastinal Tumors.—*Case* 101.—Mrs. ———, aged fifty-six, referred to me by Dr. J. B. Murphy, of Chicago, April 23, 1902. Six years ago the left breast was removed for carcinoma. Eight months before I saw her she developed hoarseness and pain in the chest. At the time she was referred to me her voice was lost and there was a large bulging tumor under the sternum. There were hard glands in the left supraclavicular space. She had a severe cough and suffered greatly from a feeling of oppression in the chest. This patient had twenty-nine exposures between April 24 and June 20, with some amelioration in her subjective symptoms, but without effect on the tumor. Since that time she has had irregular treatments at her home in another city, but without effect except in keeping her comfortable.

Case 102.—Man, aged fifty, with a history of a small lump beginning low down behind the sternomastoid muscle about two years ago. August 8, 1901, the mass was removed, but evidence of recurrence showed almost immediately, and a second operation was done October 29, 1901. The diagnosis of the specimen was "a carcinomatous or endotheliomatous structure." The pathologist found it impossible to make a more definite statement. The disease recurred promptly after the second operation, and between December 21 and January 21, 1902, he was given strong *x*-ray exposures, with the production of a dermatitis, the relief of pain, and some evidence of diminution in the tumor. March 22, 1902, after the subsidence of the dermatitis, he was referred to me. At that time there was an extensive swelling on both sides of the neck, hard and immovable, and extending down behind and to the left of the sternum. The patient was suffering

from pain and from sensations of distress in the chest. He was given vigorous *x*-ray exposures daily from March 22 to April 23, without checking the progress of the disease. The tumor gradually spread and the patient died from its effects soon after stopping treatment. No result except the relief of pain occurred from the use of *x*-rays.

Carcinoma of the Esophagus.—*Case* 103.—Mr. ———, aged sixty-five, referred to me April 4, 1902, with carcinoma of the esophagus in an advanced stage. He had forty exposures between April 4 and September 17, with, he maintained, considerable relief of pain but without material effect on the progress of the disease, from which he died in November.

Case 104.—Man, aged fifty-six, referred to me by Prof. W. S. Halsted, of Johns Hopkins University, May 7, 1902. In September, 1901, he noticed difficulty in swallowing. Before that time he had lost about ten pounds in weight, and between that time and the time he came to me he had lost about ten pounds more. During the previous eight weeks he had been in Baltimore, where he had been seen by Dr. Halsted, Dr. Kelly, Dr. Osler, and others, and an obstruction in the esophagus had been located nine inches from the teeth. At first a clinical diagnosis of carcinoma was made. Subsequently, Dr. Halsted informs me, a piece of tissue was removed through the esophagoscope and the diagnosis of adenocarcinoma was made microscopically. At the time he came to me his physical condition was good. There was a good deal of distress and some pain in the chest and he was having considerable difficulty in swallowing, but could swallow most solids after very thorough mastication. Vigorous *x*-ray exposures were begun over the upper part of the chest May 7, 1902, and from that time to the present he has had daily exposures, except Sunday, either over the chest or back, the exposures being changed as erythema developed. There was prompt disappearance of the discomfort and pain in the chest and there was gradual—never sudden—improvement in his swallowing. Six weeks after beginning the exposures, without making any changes in his habits of life, he had gained nine pounds in weight, his pain had disappeared, and he was having no difficulty in swallowing. He had to

masticate thoroughly but could eat everything. His weight eventually increased fifteen pounds. Seven months after beginning treatment he is almost at his normal weight, has no pain, swallows without difficulty, feels well, and is vigorous.

CHAPTER XIII.

DEEP-SEATED CARCINOMA.

Carcinoma of the Head and Neck.—Three cases of carcinoma of the lower jaw, in none of which did any improvement take place, have been reported by Johnson and Merrill.*

Eijkman,† on the other hand, has reported a case of advanced carcinoma of the root of the tongue, lower jaw, and neck, which under *x*-rays became entirely well; also a case of cancer of the neck in which further growth was checked by treatment.

I have treated the following cases of carcinoma of the head and neck, some of which began as epitheliomata, others as more deep-seated lesions. In all of the cases, however, except Cases 113 and 114, there were at the time treatment was begun deep-seated metastases.

Carcinoma of Neck.—*Case* 105.—Man, aged sixty-eight, referred to me by Prof. R. R. Campbell, of the Chicago Polyclinic. In the spring of 1901 he had an epithelioma removed from the lower lip, with rapid recurrence in the glands of the lower jaw and neck. A radical operation was done in June, which was followed by rapid recurrence of the disease in the supraclavicular glands. Dr. J. B. Murphy and Dr. Christian Fenger saw the patient in September, 1901, and his condition was considered inoperable.

When he began *x*-ray treatment there were tumors on either side of the neck above the inner third of the clavicle as large as an egg, and the surrounding tissue was infiltrated with carcinoma. He was put under *x*-ray exposures on September 26, and kept under daily exposure with a few intervals—the longest being ten days—for three months. Within a month after the exposures were begun and at the time that dermatitis was produced there was very marked subsidence of the tumors;

* American Medicine, 1902, iv, p. 217.

† "Krebs und Röntgenstrahlen," Haarlem, 1902.

they disappeared almost entirely and remained in this condition for six weeks. After an interval of nearly three months the case was seen again by Dr. Murphy, on December 3. He gave me his opinion at that time that the tumors had not only been checked in growth, but that they were very markedly smaller than when he had seen them three months before. Soon after this, however, they began to grow rapidly, and the patient would undoubtedly have died from carcinoma had he not been taken off by an intercurrent malady.

In this case we were hampered by the fact that the tissue transposed in the plastic operation, which was very extensive, was quite sensitive to the *x*-rays and the patient was unwilling to have the full effect of the rays produced.

Case 106.—Man, aged fifty-five, referred to me by Dr. L. L. McArthur, who had removed one-third of the tongue and the sublingual and submaxillary lymphatics for carcinoma. Later a manifestation of the disease occurred in a lymphatic near the tip of the styloid process involving the common carotid and the jugular. November 4, 1901, these lymphatics were removed and the sheath of the vessels cleared, and he was sent to me to try to prevent recurrence. This patient was given exposures over the involved area almost daily from November 25, 1901, to March 23, 1902. For the first month exposures were given cautiously and then were pushed very vigorously to the point of causing a severe dermatitis, but the exposures were never stopped on this account. There was never any evidence that *x*-rays had any effect upon the growth of the tumor. The entire side of the neck became involved and the disease caused the patient's death a short time after stopping treatment. I was never able to convince myself that any effect whatever was produced in this case except the relief of pain. That, however, was entirely controlled, so that the patient suffered practically no pain.

Case 107.—Man, aged sixty. This case is very similar to Case 106, except that there was very extensive ulceration of the tissues in this case and almost none in the previous one. The patient was operated upon by Dr. Butlin, of London, for recurrent carcinoma in the neck after carcinoma of the mouth;

and later by Dr. Maurice Richardson, of Boston. In order that he might be nearer his home, he was referred to me in January, 1901, by Dr. Richardson and Dr. F. V. Williams, who had been giving him *x*-ray exposures. In this case the floor of the mouth, the neck, and the lower jaw were riddled with carcinoma and the patient's condition was regarded from the start as almost entirely hopeless. He had very vigorous exposures and a dermatitis was quickly produced and maintained. Under these exposures there was very marked subsidence of the tumors, so that at the time of his death from exhaustion three months after beginning treatment all of the nodules of the neck had disappeared, the normal contour of the neck was restored, and some healing of the sinuses had taken place. Altogether the subsidence of the carcinomatous tissue has been remarkable. In this case also the pain was controlled.

Case 108.—Man, aged seventy-one, referred to me by Dr. A. J. Ochsner, with a rapidly growing carcinoma, the size of a fist, involving the right angle of the lower jaw. The patient continued under treatment a month and quit after there had been produced considerable softening of the tumor.

Case 109.—Man, aged seventy-one, referred to me by Dr. George F. Bradley, of Chicago. In January, 1901, an epithelioma was removed from the lip by a V-shaped incision, and in June, 1901, Dr. Nicholas Senn removed part of the lower lip and the submaxillary and sublingual lymphatics. The disease recurred promptly, and he came to me March 1, 1902, with a large ulcerating mass of carcinoma under the chin and the glands on both sides of the neck involved. Under *x*-ray exposures the pain was controlled and the large mass under the chin almost removed. The disease continued to spread in the neck, and caused the patient's death three and a half months later. The only practical result was the stopping of pain.

Case 110.—Man, aged forty-two; referred to me by Dr. A. F. Jones, of Omaha, Neb. This case is almost identical in all its details with Case 107 above. The only effect of *x*-rays was the reduction of large masses of carcinoma in the neck and the relief of pain, but the disease was not controlled and the man died of hemorrhage.

Case 111.—Man, aged sixty-eight. In this case there was recurrent carcinoma of the lip and neck after epithelioma of the lip. There was practically no effect from *x*-rays except the relief of pain and the softening and disappearing of some of the masses.

Case 112.—Man, aged fifty; referred to me by Dr. H. V. Ogden, of Milwaukee, with a primary carcinoma of the larynx and enormous carcinomatous masses on either side of the neck. This case went from bad to worse steadily while having *x*-ray exposures, which had apparently no effect except the complete relief of pain. The relief of pain in the case was striking.

Case 113.—Man, aged forty-one, referred to me by Dr. W. H. Fitch, of Rockford, Ill. In January, 1901, an epithelioma of the lower lip was removed by a V-shaped incision. At the same time the submaxillary lymphatic glands were removed. In March, 1902, another gland was removed under the chin. At the time that he came to me the lip and chin were healthy, but there was an indurated gland under the upper sterno-cleidomastoid muscle with some palpable nodules near the larynx. Between July 1 and August 9 he had fairly vigorous exposures over the suspicious areas, with the production of dermatitis and the entire disappearance of the indurated masses. Four months later there is no evidence of recurrence.

Case 114.—Man, aged forty-five, referred to me by Dr. C. M. Gleason, of Chicago. A year and a half ago an epithelioma was removed from the upper lip, the submaxillary contents being cleaned out at the same time. Eight months later a gland was removed from either side of the neck about the middle third of the sternocleidomastoid. At the time he came to me, April 15, 1902, the scars from this operation showed several small growing nodules, and the scar in the lip considerable induration. He was given thirty fairly strong *x*-ray exposures over these areas between April 15 and July 28, 1902, with the production at different times of acute dry dermatitis. By July 28 all of the induration had disappeared. The scar in the lip was soft and movable and also the scars in the neck. Four months later there is no indication of disease.

Conclusions.—In the last two cases, which resemble each

other closely, a symptomatic cure has been produced. These were both cases in which the disease was relatively superficially located. In all of the cases of well-developed deep-seated carcinoma in the neck practically no effect upon the course of the disease can be shown. Indeed, in my experience carcinomata of no other class have shown themselves so totally unaffected by vigorous *x*-ray exposures as the deep-seated carcinomata in the neck. The only effect that can be claimed is marked relief of pain, and that has not failed to result in any of the cases.

Carcinoma of Mouth and Pharynx.—S. Allen * has reported the treatment of a carcinoma of the tongue with no relief except of pain.

Brook † has reported an epithelioma of the lip and roof of the mouth in which there was long treatment with no benefit.

My experience in this group of carcinomata covers four cases:

Case 115.—Man, aged fifty-five, referred to me by Dr. O. J. Stein, of Chicago. A year and a half ago an ulcer developed on the inner surface of the left cheek just behind the last lower molar, and one year ago was removed. At the time he was referred to me there was a healthy scar at this point, but in front of it there was an ulcer the size of a little finger-nail, with indurated nodular border and evidently an epithelioma. There were large patches of leukoplakia on the tongue and over most of the buccal mucous membrane. There was on the left cheek a patch of thick white leukoplakia extending from the ulcer to the angle of the mouth. This patient was given persistent *x*-ray exposures to the point of producing an acute inflammation of the mucous membrane on several occasions. Between December 9, 1901, and October 24, 1902, he received 144 exposures. As a result of these exposures the patch of leukoplakia on the inside of the cheek cleaned up and was replaced by healthy mucous membrane, but there was no effect on the epithelioma and it has gradually spread. It seems hard to understand, in view of the effect on lesions of similar character situated in the skin, why some effect was

* Boston Med. and Surg. Jour., 1902, cxlvii, p. 431.

† Brit. Med. Jour., 1902, ii, p. 1303.

not produced in this case. The metastases in the neck would not have been expected to show any better results than have been found in other lesions in the same location, but I should have expected to cause some effect upon the lesion in the mouth.

Case 116.—Man, aged fifty-five, with an epithelioma on the inner surface of the left cheek just above the angle of the mouth. The lesion was as large as a silver half-dollar and growing rapidly. After a few vigorous exposures without effect the mass was radically removed, but the disease recurred immediately in the cheek and neck, and he was given subsequent exposures for a month without effect, when he discontinued treatment.

Case 117.—Man, aged sixty-eight, referred to me by Dr. Chas. W. Oviatt, of Oshkosh, Wis., with an extensive carcinoma involving the floor of the mouth, the under surface of the tongue, and the submaxillary lymphatics. He was given vigorous exposures for a month and a half without apparent effect.

Case 118.—Miss ———, aged twenty-eight, with carcinoma of the soft palate and tonsil, referred to me by Dr. W. S. Halsted, of Baltimore. This patient was under my care three months without apparent effect on the tumor, and she discontinued treatment.

These cases must all be put down as failures, and they simply add their weight to the evidence of the very malignant character of deep-seated growths in these regions.

Deep Carcinoma in the Orbit.—*Case* 119.—Man, aged sixty-two, referred to me by Dr. Wm. H. Wilder. He had, for several years, an epithelioma of the lower lip, which four years ago was removed. In January or February, 1901, an epithelioma appeared on the inner side of the orbit, which when he came under my care had developed until there was an extensive carcinoma involving all of the structures in and around the orbit. The growth had progressed within the cranium when treatment was begun, and he was suffering harassing pain. A shrunken eyeball remained, which, before beginning treatment, Dr. Wilder removed. Its removal in no way lessened the amount of pain from which the patient was suffering. He was given vigorous exposures and they resulted in the

prompt relief of pain. A dermatitis was produced at the end of the first month, and with its appearance the tumor mass shrank considerably. During the second month, however, in spite of vigorous exposures, the tumor grew, the patient developed most distressing intracranial pain, and there was every reason to believe that the growth was developing rapidly in the meninges. The case seemed to have gone beyond the hope of benefit, and when the disease continued to show symptoms of aggressive growth, in spite of the production of an acute dermatitis, we concluded that it was useless to give him exposures longer, and discharged the case as hopeless.

The subsequent history of this case is highly interesting. He was discharged the latter part of October, 1901, and I heard nothing further from him, and accordingly in the report of my work in April, 1902, I reported this case as a failure and the patient presumably dead. On April 30, however, almost six months after his discharge, I received the following letter from Dr. T. Sprague, of Sheffield, Ill.:

"*Dear Doctor:* I write you regarding the condition of Mr. ———, an old gentleman whom you treated for carcinoma of the right eye, discharged as incurable (if I am correctly informed by Mr. ———) about the last of November. He was a charity patient, and I think was referred to you by Dr. Wilder. He called on me on his return from Chicago, had a recipe calling for tablets of a quarter of a grain of morphin to be taken when in pain. I saw that he had about twenty tablets. I noticed the condition of his eye at that time, and concluded from my examination that it was only a question of time, and short time at that, with him. I saw him yesterday and he presents an entirely different appearance. The mass that occupied the orbit has shrunk, allowing the lids to close. He is free from pain, eats and sleeps well, uses no anodyne. There are a few little nodules on the nose near the commissure of the eyelids. With that exception he looks quite well. He has certainly gained since coming home, and I feel assured it is the result of the *x*-ray treatment. I should like you to see him again."

I regret that Dr. Sprague and I have both been unable to get a report later than April 30 upon this case, but even granting

that the disease has recurred the results in the case are extremely instructive. There was surely involvement of the intracranial tissues around the orbital bones; there was every evidence of the greatest malignancy in the growth; there was a mass of carcinoma tissue as large as an egg in the orbit and other carcinomatous tissue beyond. And the result in the case leaves no doubt of the deep-seated effect of *x*-rays. A second instructive fact is the persistence of *x*-ray effects. An acute dermatitis had caused no effect on the tumor at the time of the patient's discharge, but the *x*-ray effects were sufficiently active long after exposures were discontinued to cause destruction of the carcinomatous tissue. The results in this case would seem to warrant a persistent trial of *x*-rays in any localized carcinoma, no matter how desperate.

Carcinoma in the Abdomen.—The first report upon the therapeutic use of *x*-rays was the report of the treatment by Despeignes * of a carcinoma of the stomach improved under daily *x*-ray exposures. Skinner † has reported five cases of intra-abdominal tumor treated with *x*-rays. In two of these the growths became smaller, and in two others constitutional improvement was noticeable. In the fifth there was no apparent effect. Morton ‡ has reported the immediate relief of pain in a case of carcinoma of the stomach.

I have treated nine cases of abdominal carcinoma. The length of treatment in these cases has varied from only a week or two in one or two cases, to three or four months in others. In none of these cases is it positive that the course of the disease was particularly influenced. Most of them certainly showed some subjective improvement, and when there was pain there has been reason to think that it was positively affected; but further than this no results can be claimed. These cases were of the usual type of abdominal carcinoma, and it seems hardly necessary to consume time in an analysis of them, since none of them furnishes material evidence of the effect of *x*-rays.

* Semaine méd., 1896, xvi, p. cxlvi.

† Rev. Int. d'Electrothérapie, 1902, xii, p. 28.

‡ Med. Record, 1902, lxi, pp. 361, 801.

Carcinoma in the Pelvis.—Stuver * has reported a case of inoperable carcinoma of the uterus in a woman aged forty-five, in which there was severe pain, free discharge, and ulceration of the uterus, vagina, and rectum. Pain on examination was very great. Exposures were given through a speculum. Under daily exposures between June 25 and July 10, 1902, the discharge and odor decreased very much; the sloughing was arrested, pain was relieved so that opiates were no longer necessary, and the patient so gained in strength that she was able to walk without any assistance, even up a long flight of stairs. Hett † has reported a case of carcinoma of the cervix extending into the uterus and involving the vaginal wall, in a woman aged forty-six. Forty exposures had been given. The pain had been considerably relieved, but beyond that nothing could be said. Duncan ‡ has reported benefit in one case of cancer of the uterus, as have Hopkins § and C. W. Allen.‖

I have treated by this method six cases of carcinoma in the pelvis.

In the following two cases there has been some reason to believe that a positive effect of *x*-rays has been produced:

Case 120.—Mrs. ———, aged fifty-two, referred to me by Prof. E. C. Dudley, of Northwestern University, with an inoperable primary carcinoma of the uterus. At the time she was referred to me there was a large mass of carcinomatous tissue involving the uterus and surrounding parts, and there was a rather free purulent discharge. The patient's physical condition was fairly good. In this case vigorous *x*-ray exposures have been given from May 28 to date. The patient has had 136 vaginal exposures in addition to exposures over the hypogastric and lumbar regions. This patient was not seen by Dr. Dudley from the last of May until the last of September—four months. When he examined her the second time, it was his opinion that the mass was certainly smaller, and, to use his

* Cincinnati Lancet Clinic, 1902, N. S. xlix, p. 151.
† Dominion Medical Monthly, 1902, xix, p. 76.
‡ Interstate Medical Jour., 1902, ix, p. 531.
§ Phila. Med. Jour., 1902, ix, p. 626.
‖ New York State Jour. of Med., 1902, ii, p. 176.

expression, "did not have the same aggressive character." There has been no ulceration in the vagina, there has been practically no discharge for several months, there is no trouble with the bladder, and the patient has remained almost free from pain. She is, however, becoming cachectic and running down generally. She has been made comfortable, the vaginal discharge has been prevented, the course of the disease has perhaps been checked, but there seems little reason to expect more.

In the next case the treatment was started by me, but has been carried out entirely by Dr. Winton.

Case 121.—Mrs. ———, aged sixty, referred to me by Dr. Charles F. Winton, of Washington, Ind. There was a carcinoma of the uterus which Prof. L. S. McMurtry, of Louisville, Ky., had decided was inoperable. At the time that I saw her there was a large mass of carcinoma in the pelvis with ulceration of the vaginal wall and uterus, and with a profuse discharge. The patient was very much emaciated, was confined to her bed, was suffering much pain, and there seemed every reason to expect a quick ending of the case. The patient was seen by me March 2, 1902, and from that time until the present, except during April, when she had a lobar pneumonia, she has had on an average six *x*-ray exposures a week. Three months after beginning exposures there was marked improvement in the patient's condition. The discharge from the vagina had almost stopped, she was no longer confined to bed, her pain had practically ceased, and in every way she was very much better. A very marked improvement has been maintained. In a letter of November 28, nine months after beginning treatment, Dr. Winton reports upon the condition of the case as follows: "She is in fair condition to-day. Has some little discharge occasionally, but it is perfectly free from odor." She has been for six or seven months practically free from pain. Any opinion as to the length of time that a patient with pelvic carcinoma may live is, of course, uncertain; but it is surely true that it would have been thought impossible that this patient could live nine months when *x*-ray exposures were begun. But the prolonging of her life is not the most important consideration.

The relief of pain, the checking of the vaginal discharge, and the consequent comfort to the patient, are at least of as great importance.

In the four following cases, little besides the relief of pain can be claimed:

Case 122.—Mrs. ———, aged forty, with inoperable carcinoma of the uterus, with profuse vaginal discharge, and suffering much pain. This patient had exposures during two months with very marked relief from pain and decrease of discharge, but without further effect, and one month after stopping treatment she died.

Case 123.—Mrs. ———, aged forty, with extensive recurrent carcinoma in the pelvis, and all through the abdominal cavity. She was so ill as to be expected to die at almost any time when treatment was begun. She had *x*-ray exposures daily during November and December, 1901, and January and February, 1902. There was certainly marked subjective effect from the *x*-rays, but I think it doubtful that it was more than a psychic effect, and the course of the disease was not materially checked.

Case 124.—Mrs. ———, aged forty-five, with extensive recurrent carcinoma in the pelvis and abdomen. This patient had a month's exposures without any perceptible effect.

Case 125.—Mrs. ———, aged sixty, with a large mass of recurrent carcinoma in the pelvis and abdomen. She was treated for a short time by me and later by the physician at her home without apparent effect upon the course of the disease.

In two of the above cases (Cases 120 and 121) there seems good evidence of the positive effect of *x*-rays. At any rate, both cases have pursued much more favorable courses than was expected. Among the other four cases, certainly one of them (Case 123) pursued a much better course than was expected, but that this was due to *x*-rays is doubtful. In all of the cases there was some amelioration of the disease. Pain was lessened and the vaginal discharge checked. In the cases that have had persistent treatment the benefit in this respect has been very marked. Ulceration in the vagina has been overcome, discharge rendered odorless and almost entirely

checked, and the patients freed from pain. Such benefits, of course, are most valuable in these cases.

Carcinoma of the Anus and Rectum.—Bryant * has reported the case of an old man with a cancerous stricture of the rectum, for the relief of which colotomy had been proposed. He was treated with the *x*-rays, through the perineum, lying on his side with the legs flexed. Great relief was obtained, to the extent that the patient was able to pass feces without pain and the finger could be passed through the stricture without difficulty. Brook,† on the other hand, has reported a case of cancer of the rectum in which the sphincter ani was incised to allow the insertion of a large speculum, through which treatment was given without effect.

I have treated two cases of carcinoma of the rectum and anus by this method, but without further results thus far than the checking of discharge, the relief of pain, and some shrinkage in the size of the tumors.

Case 126.—Man, aged thirty-five, with a carcinoma involving the entire perineum and the anus, was under treatment for a month, with drying up of discharge, considerable relief of pain, and shrinkage of the tumor masses.

Case 127.—Mrs. ———, aged fifty, with rapidly growing carcinoma of rectum and anus, was under treatment for two months with effects similar to those in the preceding case. A radical operation was then performed. This I believe has not given material benefit.

In neither of the above cases was the treatment more than slightly palliative, but in neither was it possible to carry it out effectively.

* Brit. Med. Jour., 1902, ii, p. 1302.
† Brit. Med. Jour., 1902, ii, p. 1303.

CHAPTER XIV.

SARCOMA AND OTHER GRANULOMATA.

Sarcoma.—The literature of Röntgen rays contains reports of comparatively few cases of sarcoma treated by this method.

Ricketts * reported a case of probable melanotic sarcoma of the chest-wall, exposed to *x*-rays, in which there was an entire relief of pain under the exposures and marked shrinkage of the growth, but the patient subsequently died from sarcoma. Williams † has reported a case of spindle-celled sarcoma of the arm, recurrent after operation, which had had exposures twice a week for from twelve to twenty minutes—fourteen, in all, at the time of report. In this case almost all of the induration has disappeared, the swelling has subsided, and the color of the skin has changed from red to normal. Beck,‡ of New York, has reported a case of recurrent melanosarcoma of the thigh and groin, which under vigorous *x*-ray exposures showed marked checking of the course of the disease, but in which it was hardly possible, in Beck's opinion, to expect relief. Kirby§ has reported a very interesting case of round-celled sarcoma treated successfully by *x*-ray exposures. The patient, a man aged sixty-four, with a cancerous history, developed after a traumatism a swelling in the neck which remained quiescent for sixteen or eighteen months. After a severe wrench of the neck it began to grow rapidly and became painful. At the time that the case came under observation there was an inoperable tumor as large as a goose-egg, firmly fixed, with indurated borders and with surface dark and tense. Soon after it began to ulcerate. The pain was most severe. Under six weeks' vigorous treatment the tumor disappeared, the surface healed,

* Jour. Am. Med. Assoc., 1900, xxxiv, p. 76.

† "The Röntgen Rays in Medicine and Surgery," p. 666.

‡ New York Med. Jour., 1901, lxxiv, p. 906.

§ Journal of Advanced Therapeutics, 1902, xx, p. 89.

pain ceased, and the patient became able to resume his work. The case was symptomatically cured.

Seabury Allen * has reported a case of sarcoma of the tonsil treated by *x*-rays, with shrinking of the tumor and great improvement in eating and talking, but without complete disappearance of the disease at the time of report.

Coley,† in a recent thoughtful review of the subject of the treatment of sarcoma with Röntgen rays, has reported upon ten cases of sarcoma which he has treated with Röntgen rays as follows:

Case 1, small round-celled sarcoma of the neck, breast, and axilla, microscopic diagnosis, previously treated by operation in the axilla and by injection of toxins. The condition on February 10, 1902: "Tumor masses encircled entire neck from the mastoid process to the clavicle on the left side; on the right side involving the entire cervical, supraclavicular, pectoral, and axillary regions. The largest protuberance was in the right cervical region, about the size of two fists. The constriction of the trachea was so great as to cause frequent and severe attacks of dyspnea." With four or five exposures per week there was at the end of three weeks a "marvelous change." The tumors had decreased in size fully one-third and had become very movable. June 5 there remained on the left side only one or two nodules not larger than peas; on the right side the mass as large as two fists had become the size of an olive. There was a small nodule the size of a hickory-nut in the right axilla. All of the other tumor masses had entirely disappeared. The patient had entirely recovered her general health and took daily walks and drives. The nodule in the neck was removed and found still to show the typical structure of a round-celled sarcoma. "The patient left the hospital entirely well, July 8, 1902."

Case 2, sarcoma of femur. There was a fusiform enlargement of the entire lower two-thirds of the femur. Under a month of *x*-ray exposures the tumor decreased an inch in circumference. On the discontinuance of treatment for two weeks

* Boston Med. and Surg. Jour., 1902, clxvii, p. 431.

† American Medicine, 1902, iv, p. 251.

the tumor increased an inch. When treatment was resumed, the tumor decreased two inches in three months. The patient was losing weight and there was evidence of metastases in the lungs.

Case 3, small round-celled sarcoma in the pectoral region. It decreased in size under treatment with Coley's fluid, but with *x*-rays alone for two weeks there was no visible decrease. After that, under toxin injections and *x*-ray treatment combined, there was entire recovery.

Case 4, round-celled sarcoma of the fascia of the thigh, was entirely unaffected by *x*-ray exposures.

Case 5, a very rapidly growing round-celled sarcoma of the parotid. Only five exposures were given, and there was no effect.

Case 6, a recurrent melanotic sarcoma of the iliac glands. Under *x*-ray treatment for three weeks there was slight diminution in the size of the tumors, but the patient was steadily losing weight.

Case 7, recurrent spindle-celled sarcoma of the upper jaw, involving entire right superior maxillary region and extending into the roof of the mouth and the pharynx. There was striking improvement under use of toxins. Later *x*-ray exposures were tried for three weeks with no noticeable effect either on the growth of the tumor or on the pain.

Case 8, a recurrent, small round-celled sarcoma of the gracilis muscle. Under a month's treatment with *x*-ray exposures alone the tumor did not increase perceptibly. Afterward, under injection of streptococcus cultures and toxins combined with *x*-ray treatment, the tumor at first decreased but later increased.

Case 9, small round-celled sarcoma of the back following a traumatic hematoma. The tumor disappeared entirely under three *x*-ray exposures a week for three months.

Case 10, sarcoma of the parotid. An irregular protuberant tumor ulcerating at several points, extending from the orbit to below ramus of jaw and from left ala nasi to mastoid process. Under *x*-ray exposures a great deal of the tumor at first sloughed away, the pain decreased, the tumor mass steadily shrunk and became less vascular; later it began to increase under the angle of the jaw and the use of toxins was begun.

In addition, he reports upon four other cases of sarcoma treated with *x*-rays, which he had observed. Case 1 was a small round-celled sarcoma of the neck which had recurred six times. Under treatment with mixed toxins there was slight temporary benefit. On the left side of the neck, extending down from behind the ear, there was a large tumor the size of a double fist, in the right axilla another the size of a goose-egg. Under *x*-ray exposures there was immediate improvement. In four weeks the masses had entirely disappeared; though exposures were made only over the neck, the axillary tumor softened within three or four weeks and eventually it also entirely disappeared. There was no recurrence four months after cessation of treatment.

Case 2, spindle-celled sarcoma of abdominal wall. A tumor the size of a cocoanut in scar of operation, involving abdominal muscles. Temporary benefit from toxins. Under *x*-ray exposures the patient's general health had greatly improved, but the tumor had increased slightly in size.

Case 3, recurrent, small round-celled sarcoma of the superior maxilla. Temporary improvement under the use of toxins. Four months' treatment under *x*-rays had caused a marked decrease in size of the tumor and decided improvement in the patient's condition.

Case 4, osteosarcoma of the mastoid and temporal bone. Toxins had been used with some benefit. Under *x*-ray exposures there was immediate and almost entire relief of severe pain. After four months of treatment the tumor had almost disappeared.

Coley comments upon his cases as follows: "While none of these cases can as yet be reported as a cure, they nevertheless furnish the strongest grounds for encouragement. It seems proved that in a certain proportion of malignant tumors we have found an agent that will cause the disappearance of the growth after all other means have failed. Whether the patients will remain well sufficiently long to justify us in calling them cured, time alone will tell. The entire disappearance of a large tumor of the neck in four patients—Skinner's, of New Haven, Pusey's, of Chicago, Fiske's, of Brooklyn, and my own case,

of much more extensive round-celled sarcoma of both sides of the neck, clavicular and axillary regions (the diagnosis of sarcoma being confirmed in every case by competent pathologists)—gives us great cause for congratulation. When we consider how large a proportion of sarcomas have their origin in the neck, and how hopeless they have proved to operative treatment, we realize the importance of these recent observations. . . . I have never yet seen a case of sarcoma of the neck cured by operation, nor have I been able to find an authentic case reported by other surgeons; hence, if in the *x*-ray we have a means of destroying these growths, or a certain proportion of them, it means a great advance over present methods."

I have treated with *x*-rays eleven cases of sarcoma.

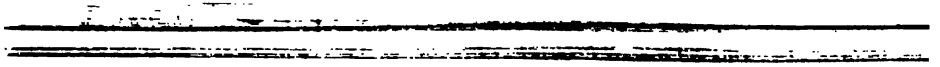
Case 128.—Man, aged twenty-four, referred to me by Dr. A. J. Ochsner, September 2, 1901. In February, 1901, he noticed a hard swelling behind the angle of the jaw, two inches below the ear on the left side of the neck, which gradually increased in size. In May a similar hard swelling appeared on the right side of the neck, and this rapidly increased. By August there had developed large immovable swellings on either side of the neck, the size of a fist, and he then consulted Dr. Ochsner. Dr. Ochsner made a diagnosis of sarcoma, and on August 19 removed the tumor on the left side of the neck. The microscopic examination of the tissue was made by Prof. F. R. Zeit, of Northwestern University, who made a diagnosis of round-celled sarcoma. Two weeks after the operation on the left side of the neck Dr. Ochsner sent him to me to have *x*-ray exposures given while he was getting in condition to have the operation on the other side. At that time there was a healthy scar on the left side of the neck and a large swelling on the right side, as shown in figure 159. This was a hard, diffuse, immovable tumor, and involved so much tissue that the neck was rigid. He was given vigorous *x*-ray exposures and the tumor mass began to subside immediately. At the end of four weeks an acute vesicular dermatitis was caused, and by that time the tumor had entirely disappeared, as shown in figure 160. In four weeks the circumference of his neck had decreased from 17½ inches to 14 inches. The only trace

Fig. 159.—Primary sarcoma of the neck. Case 128.

Fig. 160.

Fig. 161.—Case 128. Recurrence on both sides of the neck.

Fig. 162.



left of the tumor was a gland over the middle of the sterno-cleidomastoid muscle not larger than an almond kernel. As soon as the tumor disappeared he discontinued treatment, against my protest. After stopping treatment the first of October, the dermatitis promptly subsided, and without further treatment there was no evidence of return of the disease until March 1, 1902—five months. The first of March he discovered the development of a hazelnut-sized nodule under the angle of the right lower jaw, and at the same time a similar growth on the left side of the neck. These rapidly grew, but he did not return for treatment until March 31. When he returned March 31, there were large tumor masses on either side of the neck, the chain extending from the mastoids to the clavicles. (See Fig. 161.) They were very hard and many of them not movable. It is an interesting fact that the recurrence on the left side of the neck, which had been treated surgically, was greater than upon the right. He was given vigorous exposures on both sides of the neck for five weeks, from March 31, 1902. The tumors in the neck disappeared entirely and never afterward returned (Fig. 162). He again discontinued treatment against my protest. Six weeks later he returned. There was no recurrence on the outside of the neck, but there was a swelling the size of a small egg in the right tonsil, which was causing some difficulty in swallowing, and numerous small nodules were present in the skin or just under the skin on many parts of his body. From June 19 he was given vigorous exposures over the various tumors that developed. The tumor of the tonsil and numerous subcutaneous tumors disappeared. After he began treatment many new subcutaneous tumors developed, and between the middle of June and the middle of September a great number of these disappeared under *x*-rays. During this time he was rapidly running down, and the latter part of September symptoms of brain tumor developed and the patient rapidly went from bad to worse.

The physical condition of this patient when he first came under my care in September, 1901, was getting bad and he was suffering considerable pain. With the relief which he got in September, 1901, and again in April, 1902, his physical con-

dition began to pick up very much and his pain disappeared. Indeed, he felt so well after each of these treatments that he could not be convinced that it was necessary for him to stay longer from his work, so that it was impossible to give him as thorough treatment as I felt sure at that time was necessary. It is perhaps probable that this patient would have had metastases no matter how thoroughly the lesions in the neck might have been treated, but it is impossible to avoid feeling that had I been able to continue the persistent treatment of this case as I desired the disease might have been eradicated. Nothing could have proved more susceptible than these tumors to *x*-rays. Certainly there seems good reason to believe that the chance of their eradication would have been as good as the chance of permanent cure after operation upon any sarcoma.

Case 129.—Man, aged sixty-seven, osteosarcoma of the right shoulder, with symptoms of sarcoma of the bladder. There was profound cachexia and evidence of general sarcomatosis. The patient was put under *x*-ray exposures, chiefly with the hope of relieving his pain. He was given sixteen exposures without effect upon the tumor, but, according to his voluntary statement, with considerable relief from pain. With my approval the treatment was discontinued.

Case 130.—Woman, aged sixty, with extensive inoperable sarcoma, involving the right pectoral muscles and shoulder. She had treatment for a month, with marked relief from pain according to her voluntary statement, and in the opinion of her physician, Dr. William Fuller, but without further effect.

Case 131.—Child, aged four years, referred to me by Dr. Charles F. Roan, of Chicago. In January, 1902, a tumor the size of half an apple was discovered under the vastus externus of the left leg, and was removed by radical operation in April. Diagnosis of sarcoma, or infected granuloma, was made by Professor Zeit, of Northwestern University. Almost immediately after the operation another tumor the size of a walnut was found under the external oblique. It grew rapidly and was removed by another operation July 2, 1902. At the time she was referred to me there was a large tumor which began in the cicatrix of the second operation, and had rapidly grown

until it occupied the lower half of the anterior abdominal wall. The abdominal wall was greatly thickened, the skin was involved over almost the entire extent of the tumor, and the tumor was immovable. The left leg was enormously swollen. There was also a tumor the size of a goose-egg that had recurred in the scar of the left leg. The child was cachectic and running down rapidly, had no appetite, and suffered intense pain. Vigorous daily exposures were begun on September 1, 1902, with almost immediate relief of pain. In ten days there was a perceptible shrinking of the tumor, the appetite was better, she was sleeping better than she had for months, and looked very greatly improved. The exposures were carried to the point of producing an acute vesicular dermatitis at the end of a month, by which time the tumor in the abdominal wall had almost entirely disappeared. Until the middle of October the general improvement was maintained, but it was evident that the disease was spreading, and on November 8 the child died from general sarcomatosis. The gain in this case was the relief of pain, which was permanent and very marked, and the temporary improvement in the child's physical condition.

Sarcoma of Parotid.—*Case* 132.—Mrs. ———, aged forty-nine, referred to me by Dr. A. J. Ochsner, on April 22, 1902, with the following history: For a year past she had been having pain in the right ear and in the right temporo-maxillary articulation. For three months past this had been of most harassing character. Three months before I saw her a hard swelling had developed in front of the right ear and rapidly increased in size. When she came to me there was a hard nodular mass in front of, below, and behind the right ear, extending deep into the neck, and immovable. The whole mass was as large as a fist and formed a conspicuous tumor. In the side of the neck below the tumor there were a number of enlarged indurated glands. From pain and loss of sleep the patient's condition was much reduced. She had been seen by Dr. Ochsner, Dr. Senn, and Dr. Fenger, and it had not been deemed advisable to operate.

She was put under strong *x*-ray exposures on February 26, 1902, and between that date and April 10 she received thirty-

four exposures without the production of a marked dermatitis. On March 20, after seven exposures (she had not received more because she was physically unable to come for treatment), the following note was made: "Tumor a little softer, slept well last night; not nearly as much pain as previously." On March 31, the patient having had vigorous exposures on alternate days since March 20, it was noted that "there is not nearly so much pain. Tumor is smaller." From April 1 to May 10 she had strong exposures almost daily. At that time she was taken acutely ill with what was called neuralgia of the stomach, and she had no further treatment for six weeks. When she returned, June 15, she reported that she had had almost no pain until within the last week, and the tumor had almost entirely disappeared. There was no visible swelling and the only induration left was a small mass the size of an almond below the ear. From June 23 until the present she has had treatment more or less regularly, having had, up to November 12, 46 exposures. The tissues have been kept markedly pigmented but there has been no acute dermatitis. There has been no evidence of return of the mass. There is now no tumor apparent and no induration to be found. All of the glands in the neck also have disappeared. There has been practically no pain in this region since the disappearance of the tumor, five months ago. The patient still has pain in the left side of the abdomen just below the border of the ribs, but no tumor is demonstrable.

Case 133.—Mrs. ———, aged sixty-five. Sixteen years ago a tumor of the tonsil was removed, which on microscopic examination proved to be a round-celled sarcoma. Seven years ago a small swelling appeared in front of the ear, and another below and behind it. They remained about the size of a filbert and movable until August, 1901, when they began to grow rapidly. At the time she was referred to me there was a tumor in front of and below the ear larger than a fist, consisting of three masses that had become confluent. They were densely hard and immovable, the patient was suffering a good deal of pain, and there was paralysis of the facial nerve. This patient had vigorous *x*-ray treatment in May, June, July, and August; receiving, in all, 65 exposures. There was slight shrinkage in the tumor

temporarily, but its course was not markedly checked and the patient died from its effect September 18, one month after stopping treatment. There was marked relief from pain in this case, but no other effect.

Case 134.—Mrs. ———, aged thirty-five. In April, 1901, a tumor the size of a hazelnut was discovered in the right axilla, which by September, 1901, had increased to the size of a large walnut, and was removed. On examination it proved to be a small round-celled sarcoma. When she was referred to me, April 22, 1902, the scar was healthy, but there were two large, hard, supraclavicular glands and two nodules in the abdominal wall, one the size of a hazelnut, the other the size of a pea, both of them quite hard. Her physical condition was not good; she was very anemic, had no appetite, and was having night-sweats. For three months she had vigorous exposures over this area, with the production at several times of an acute dermatitis. All of the nodules gradually became smaller, so that by July 28 the masses had entirely disappeared. There was continuous improvement in her general condition, her appetite became good, she became much stronger, and the night-sweats ceased. This was her condition when treatment was discontinued, August 1, 1902. This is a case in which there is every reason to expect metastases in other parts, but the effect upon the lesions at the time she was under treatment was all that could have been desired.

Case 135.—Mrs. ———, aged sixty-two, with enormous osteo-sarcoma of the shoulder, which had been developing since an injury three years and a half ago. This patient had vigorous *x*-ray exposures at my hands from February 19, 1902, to June 17, 1902, without material effect upon the size of the tumor. There was, however, marked relief of pain. She was suffering harassing pain previous to the beginning of *x*-ray exposures, and this was in great part stopped by the treatment.

Case 136.—Man, aged forty, referred to me by Dr. W. B. Fiske and Dr. L. L. McArthur, of Chicago, September 22, 1902. Six months ago he noticed a painful lump on the left side of the breast. It grew very slowly until the last month, when it rapidly extended. At the time he was referred to me there

was a large tumor mass occupying the whole front of the chest between the anterior axillary lines on either side and from the manubrium of the sternum to the ensiform cartilage. It was densely hard, of purplish color, and involved the skin. There were indurated nodules in either axilla. Over the center there were a few small ulcerating points. He had moderate pain. A piece of this tissue was taken for microscopic examination, but unfortunately it was never possible to get a satisfactory report upon it. The only part that the pathologist got was the overlying skin. Clinically there was every reason to believe that it was sarcoma. It is hardly possible that it was a syphilitic gumma; the patient had no history of syphilis and had no anti-syphilitic treatment while under *x*-ray exposures. The mass was over a foot in diameter and three inches thick at the center, almost without ulceration, and bore no clinical resemblance to a syphilitic gumma.

This patient was put under vigorous daily *x*-ray exposures September 23, and the effect was little short of marvelous. By September 29 the ulcers had dried up and were healed over and the circumference of his chest had decreased an inch. On October 6 there was marked diminution in the size of the tumor. He was feeling much better and his pain was much diminished. After this the improvement was continuous. On November 1 the tumor mass had entirely disappeared from the chest-wall, the normal contour was restored, and the glands had disappeared from the axilla. The only trace of the tumor left was slight œdema over the lower part of the sternum. The improvement has been maintained. At no time has more than a slight erythema been produced. The case seemed so hopeless when treatment was begun that I failed to photograph it, but some idea of the change in the condition may be gained from the difference in chest measurements at different times. The circumference of the chest at the nipple line, on full expiration, was as follows:

September 23	38½ inches.
October 1	37½ inches.
October 6	35½ inches.
October 17	34 inches.

Fig. 163.—Result of the treatment of sarcoma of the front of the chest. White line indicates original outline of the tumor.

The change in this case can hardly be overstated. It is extremely unfortunate that the diagnosis of sarcoma in the case cannot be confirmed microscopically, but the clinical diagnosis was made by Dr. McArthur and Dr. Fiske, and there is, I believe, almost no room for doubt upon that point. The condition March 1, 1903, is shown in figure 163; the approximate outline of the tumor is shown with fair accuracy by the white line above the sternum.

Case 137.—Man, aged sixty, referred to me by Dr. F. E. Stevens, of Bristol, Wis. March, 1902, he had a group of glands removed from the left side of the neck, which upon microscopic examination proved to be round-celled sarcoma. These had appeared about a year before the operation and gradually increased in size. Soon after the operation there reappeared under the scar swelling which increased slowly. At the time he was referred to me, August 6, there was a tumor at the junction of the upper and middle thirds of the sternocleidomastoid muscle the size of a large olive. It was hard, lobulated, painless, and freely movable. Above this there were three hazelnut-sized nodules attached to the skin in the line of the scar. From August 6 to date the patient has had fifty-five exposures, with the production of a dry dermatitis twice. Under these exposures the masses rapidly shrank, until during the last month they are just palpable and are almost as soft as normal tissue.

Case 138.—Man, aged forty-one. A year ago a nodule developed in the lower lip which was removed by a V-shaped incision and which proved to be giant-celled sarcoma. There was rapid recurrence in the scar, and when he came to me the entire lower lip was involved in a disc-shaped, densely hard infiltration, with an ulcer perforating the lip at the center. He had had *x*-ray exposures for two months previously without effect. At my hands he was given the most vigorous exposures between July 1 and September 18, with the production of a very acute weeping dermatitis, but there was no effect either on the pain or on the size of the tumor. Without exception I have never seen any tumor other than osteosarcoma so hard, and the denseness of the infiltration

may perhaps account for the failure to relieve pain. By September 18 he had a severe *x*-ray burn, which was accompanied by a marked softening of the mass. December 15: Without further treatment the tumor is reduced to one-half its first size, the pain has disappeared, the patient no longer needs morphin, and his general condition is much improved.

An analysis of these eleven cases is not discouraging. In Cases 129, 130, 131, and 134 there was general sarcomatosis when treatment was begun, and that more than palliative results would be obtained was not expected. One, Case 138, is perhaps a complete failure. Case 135 is also a failure except for the relief of pain, but that was a case of osteosarcoma so extensive that anything more than palliation is hardly conceivable. In the other cases the results, while by no means conclusive, are yet of a most striking character. Cases 132, 136, and 137 are symptomatic cures. The patients have been relieved of pain, have been restored to health, and the tumors have disappeared. If these cases had been operable, and they were not, no better results could have been obtained. Case 128 has proved an ultimate failure, but the failure is not altogether to the discredit of the method. Opportunity was not offered for giving adequate treatment. If there had been sufficient treatment at the start, and a repetition of exposures at frequent intervals over the area of the disease, it seems possible, so remarkable was the course of the case, that a better showing might have been made. These cases all illustrate the importance of having patients as early as possible for treatment. It cannot be expected that more than palliation can be attained unless the cases are gotten for treatment before general sarcomatosis has developed.

Sarcoma of the Eye.—Harper * has reported a case of melanosarcoma of the sclera, which was treated after operation to prevent recurrence. There remained after the operation three dark spots of pigmentation, which disappeared under *x*-ray exposures. Nine and a half months after the operation there was no evidence of recurrence.

I have treated one case of glioma, recurring after operation for glioma of the retina.

* American *X*-ray Journal, 1902, iv, p. 1164.

Case 139.—Negro child, aged four years, referred to me by Prof. Casey Wood, of the University of Illinois. In this case there was a large tumor mass filling the orbit when the treatment was begun. The exposures were pushed, with little expectation of a cure, in order to prevent the development of the large protruding tumor of the eye that was to be expected in the case. The exposures prevented the development of the tumor on the surface, and in Dr. Wood's opinion the case pursued a much slower course than would ordinarily be expected. The child ultimately died, but without the development of any external tumor.

Mycosis Fungoides.—Walker * states that Jamieson has treated with *x*-rays a case of mycosis fungoides with very marked improvement. Scholtz † reports that in two cases of mycosis fungoides premycotic areas and small tumors disappeared entirely under exposures sufficient to cause superficial necrosis.

Case 140.—I have treated with *x*-rays for a short time one case of mycosis fungoides. A large tumor mass on the back of the head, and two patches of induration which were just beginning to show the formation of tumors, were exposed every other day for one month with very great improvement. There were innumerable lesions, however, over the body, and we were not making progress sufficiently fast to please the patient, so he declined further treatment. There would seem to be good reason to expect great benefit from the use of *x*-rays in mycosis fungoides. The condition usually remains without deep metastases, and from the results in the few cases that have been treated it seems likely that these tumors could be controlled by *x*-ray exposures. The extent of the lesions would make the treatment tedious, but there seems reason to hope that the course of this disease may be markedly benefited by the persistent use of *x*-rays.

Granuloma of Uncertain Character.—*Case* 141.—Man, aged fifty-seven, referred to me by Dr. A. J. Ochsner. Patient came to Augustana Hospital, in Dr. Ochsner's service, October 20, 1901,

* Brit. Med. Jour., 1902, ii, p. 1319.

† Arch. f. Derm. u. Syph., 1902, lix, p. 421.

when the following history was taken: "Two months ago a carbuncle developed on the right cheek. The whole right side of face became painful and swollen; this swelling subsided, and three weeks ago the patient noticed a small soft swelling at site of carbuncle. This has increased to present size. Has been opened three times, discharging blood and serum. No tenderness or pain. Present condition: Right cheek slightly reddened and indurated. Downward and forward from malar bone a soft swelling with few crusts, 2.5 cm. in vertical diameter and 2 cm. in horizontal diameter. On pressure, discharges sero-purulent fluid. Mucous membrane on inner surface opposite tumor, smooth." Dr. Ochsner removed the entire mass, going well out beyond the diseased tissue, and closed the wound. The wound remained clean, but failed to heal, and the tissues around began to break down, and within two weeks there was an unhealthy ulcer with a cavity the size of an olive, surrounded by bluish, flabby tissue. The pathological findings were not definite. It was a granuloma with numerous giant cells, but its character was not definitely determined. The case was then, November 2, 1901, put under daily *x*-ray exposures, and practically no attention paid to the local dressing. In two weeks some dermatitis was produced, and the ulcer began rapidly to fill up. In three weeks it was healed with a perfectly healthy scar, and has remained well. The diagnosis in this case was not positive, but in Dr. Ochsner's opinion there was strong probability of its being sarcoma, and it gave every prospect of being a lesion which would be difficult of handling by the usual surgical procedures.

Case 142.—Granuloma of uncertain character, probably blastomycosis. Mrs. ———, aged forty-three. Six years ago patient received a blow below the left knee, followed by hematoma which was six months in disappearing. This was followed by a lump under the skin about 2 cm. in length, which slowly enlarged, grew dark red, and finally ulcerated. In 1899 the ulcer with the surrounding tissue was removed. The wound healed, but after several months ulceration again occurred, and the condition has persisted during the subsequent two and a half years. The family and personal history were negative.

Fig. 164.—Blastomycosis (?) of the knee.

Fig. 165.

Patient has had no miscarriage. All the children were healthy in infancy, the only one to die dying of cholera morbus. She has had no skin eruptions, no loss of hair, no sore throat. The physical condition is negative—a tall, sparely built woman, somewhat anemic and nervous. The condition at the time she came under my care is shown in figure 164. There was a large, soft, purplish tumor involving the knee on the front and outside. The apex of this mass was occupied by a superficial, indolent, horseshoe-shaped ulcer, surrounded by raised, puffed edges. A superficial slough covered nearly the whole surface. The entire mass was movable, extraordinarily soft and flabby, of a dark purplish color, and markedly pigmented. Around the periphery of the tumor the surface was roughened by a verrucose, papillary thickening of the skin. The patient had been unable to use the leg, and had been on crutches over a year. The case had proved totally unamenable to treatment and amputation of the leg had been advised.

The diagnosis lay between syphilitic gumma, tuberculosis, sarcoma, and blastomycosis. The first three were almost entirely excluded by the history of the case and its course and the appearance of the lesion. It resembled no other lesion that I had ever seen. The probability of its being blastomycetic dermatitis did not occur to me until after it had been under treatment for two weeks, during which time there had been marked improvement under *x*-rays and 1 : 10,000 bichlorid wet dressings. I never succeeded, therefore, in making cultures of the organisms. As soon as the nature of the condition was suspected a piece of tissue was taken for examination and attempts at cultures made, which were unsuccessful, perhaps because of the treatment. The salient points in the histological examination of the tissue, made by Mr. Ruediger, are as follows: "The rete appears to be in marked hyperplasia, producing branching down-growths which form an irregular network within the corium. Leucocytes in various numbers are scattered throughout the branching epithelium and frequently appear in small collections forming intercellular abscesses. Besides polymorphonuclear leucocytes, plasma cells, red blood-corpuscles, detached epithelium, and debris of various kinds are seen

within the abscesses. The corium contains a large number of polymorphonuclear leucocytes, plasma cells, and red blood-corpuscles, the leucocytes frequently forming dense abscess-like collections similar to the abscesses within the epithelium. The characteristic branching hyperplasia of the rete, together with the intra-epithelial abscesses, indicate strongly in my opinion blastomycetic dermatitis."

X-ray exposures were begun on the leg on March 3, 1902, and between March 3 and June 2 she received eighteen *x*-ray exposures, at an average distance of 7 cm. and of an average duration of fifteen minutes, with a fairly strong light. Two weeks after beginning treatment, when blastomycosis was suspected, she was given ten grains of potassium iodide three times daily. During the two weeks preceding the administration of the iodide there had been very decided shrinkage of the tumor and decrease in size of the ulcer. From the start the improvement was continuous, and by June 2, the tumor had entirely disappeared and the ulcer was replaced by healthy scar tissue (Fig. 165). The function of the knee was not damaged, and she was using the leg without crutches, as she has continued to do since that time. The case had seven exposures between June 2 and July 2, as a prophylactic measure. Since that time there have been no exposures and the leg remains perfectly well. At no time during the treatment was there produced more than the slightest evidence of *x*-ray reaction. The subsidence of the mass was most remarkable, particularly when one takes into consideration its course and its apparently malignant character. During the entire time of treatment the leg was dressed daily with 1 : 10,000 bichloride dressing. During most of the time that she was under treatment the patient had ten grains of iodide of potassium three times daily, and that, of course, militates somewhat against the conclusiveness of the demonstration of effect of *x*-rays in the case. The patient had, however, previously had vigorous treatment with potassium iodide without effect. Moreover, iodide of potassium, to be effective in blastomycetic dermatitis, has to be given in large doses, and while such doses of potassium iodide have a marked favorable effect upon blastomycetic dermatitis, the use of

potassium iodide alone has not been found sufficient to cure the cases entirely. Vigorous local treatment of the lesions has to be called to its aid. There can be, therefore, little doubt of the fact that the result in this case was almost entirely due to the effect of *x*-rays.

CHAPTER XV.

THE PROPHYLACTIC USE OF X-RAYS AFTER OPERATIONS FOR MALIGNANT DISEASES.

THE use of *x*-ray exposures after operations for malignant tumors as a method of prophylaxis is unquestionably a logical procedure, and it is being carried out at the present time by many workers. The time, however, is too short for any data upon the subject to be valuable. The method was first undertaken by me in June, 1901, at the suggestion of Prof. T. A. Davis, of the University of Illinois, on a patient of his, and I have been using *x*-rays in this way since that time. I have records of twenty-one cases of carcinoma or sarcoma in which the procedure has been carried out, and in which considerable time has elapsed since operation. The cases are as follows:

14	cases	after	operation	for	carcinoma	of the	breast
1	case	"	"	"	"	" "	jaw.
1	"	"	"	"	"	" "	uterus.
1	"	"	"	"	"	" "	rectum.
1	"	"	"	"	"	" "	lip.
1	"	"	"	"	sarcoma	" "	muscles of the shoulder.
1	"	"	"	"	"	" "	finger.
1	"	"	"	"	"	" "	iris.

Of course, the list is not large enough, and the time that has elapsed is not long enough, to allow of any deductions as to the value of the method. The course of some of the cases, however, is such as to give good reason to believe that the use of *x*-rays has had a positive influence in preventing the recurrence of the disease. Such cases are as follows:

Case 143.—Mrs. ———, aged forty-five, referred to me by Dr. T. A. Davis, of Chicago, after radical operation for removal of the breast. The operation had been done eight weeks previously. At the time of beginning treatment there was a healthy scar, but the arm was œdematous, and she had a good

deal of pain. In Dr. Davis's opinion the danger of recurrence within a few months was very great. The case has had several series of *x*-ray exposures between June, 1901, and the present time, the reaction being carried each time to the point of producing a moderate dry dermatitis. Soon after beginning treatment the swelling in the arm and the pain began to diminish. This continued until she was practically free from pain, and the arm had gotten free from œdema. Four months after beginning treatment the arm swelled again, and Dr. Davis and I both expected that the recurrence was at hand. Under *x*-ray exposures, however, the swelling disappeared, and the patient remains well at the present time, sixteen months after the operation.

Case 144.—Man, aged sixty, referred to me by Dr. A. J. Ochsner. In March, 1898, Dr. Fenger removed the right side of the lower jaw, and in three subsequent operations, October, 1899, May, 1900, and January, 1901, he removed recurrent masses of carcinoma in that side of the face and neck. This patient was referred to me by Dr. Ochsner July 1, 1902, with a view to overcoming a possible recurrence. There were no masses palpable, but he was beginning to have some pain in the region of the operation and other subjective sensations such as had preceded the former recurrences. He has had *x*-ray exposures between July, 1902, and the present time to the point of causing thinning of the beard and producing a slight dermatitis on several occasions. As a result, his pain promptly ceased and has not returned. In October, 1902, he was examined again by Dr. Ochsner, and in Dr. Ochsner's opinion was well. It is now fourteen and a half months since the last operation and the longest previous respite was nine months.

Case 145.—Mrs. ———, aged thirty-seven, referred to me by Dr. A. J. Ochsner. October 12, 1901, Dr. Ochsner did a hysterectomy for carcinoma uteri, removing at the same time part of the bladder-wall which was involved. There was great fear in this case of recurrence. This patient had four series of *x*-ray exposures between November 30, 1901, and August 30, 1902, and the exposures are to be given again in January, 1903. There has been no evidence of recurrence of the disease. The

patient has gained flesh, has been entirely free from pain and is in her normal robust health, a year after operation.

Case 146.—Mrs. ———, aged forty, referred to me by Dr. A. J. Ochsner, of Chicago, and Dr. W. J. Mayo, of Rochester, Minn. Four weeks previously a growth had developed after a bruise on the inner side of the left thumb. This was recognized as a sarcoma, and immediately excised. Microscopic diagnosis showed it to be round-celled sarcoma. Nothing was done except the excision of the growth, as the patient refused a more radical operation. When she was referred to me, March 3, 1902, there was every reason to believe that metastases would develop almost immediately in other parts of the body. Dr. Ochsner stated to me that if she did not show sarcoma elsewhere within a few months there could be, in his opinion, no doubt as to the positive effect of the *x*-rays. The most intense exposures were begun and given daily over the thumb. There was hardly an appreciable dermatitis, but under *x*-rays the tissues of the thumb shriveled up until they looked almost mummified. Exposures were also given over the entire length of the arm, the axilla, and the mediastinal glands. She was under treatment for only a month and a half. Up to the present time, after nine months, there has been no recurrence.

It is interesting to contrast with this an identically similar clinical picture, in a patient with a sarcoma on the inner side of the middle finger, who was referred to me by Dr. H. N. Moyer, of Chicago, on July 1, 1901. The case was recognized as a sarcoma, and I advised a radical operation, to be followed by *x*-ray exposures. The patient did not have this, but within three weeks after the first evidence of the tumor he had the mass excised, and there was prompt healing. He sent me the tissue and it proved to be round-celled sarcoma. He did not have any *x*-ray exposures and within three months other tumors developed. On June 1, 1902, eleven months after the operation, he was in the last stage of general sarcomatosis.

Case 147.—Mrs. ———, aged forty-five, referred to me by Dr. E. J. Mellish, of El Paso, Texas, on November 1, 1901. She had just recovered from an extensive operation for small round-celled sarcoma, beginning on the upper and back part

of the right shoulder, and Dr. Mellish was very fearful of recurrence in the case. This patient has had several series of exposures during the last year, and there is at present, fifteen months after the operation, no evidence of recurrence.

In one case treated after operation for carcinoma of the breast there has been a recurrence in a gland under the pectoral muscle and in a supraclavicular gland. The pectoral gland was removed and under *x*-ray exposures the supraclavicular gland, which appeared six weeks ago, has now disappeared.

The cases narrated above in which there has been no recurrence of course prove nothing, because they are too few, the time is too short, and we do not know that there would have been recurrences if there had been no prophylactic exposures. Nevertheless, these were patients with the most gloomy outlook, and their surgeons had the greatest fears of early recurrence; and the fact that the recurrences have not developed after a year or more is of some significance.

The Use of X-rays Preliminary to Operation.—*X*-rays will also doubtless have a field of usefulness in the treatment of cases of malignant disease, preliminary to operation, where for any reason it is not advisable or is impossible to have the operation without some delay. The situation where this use of the *x*-rays suggests itself most naturally is in cases which must be built up before operation. In such cases it would doubtless be possible at times to inhibit the development of the growth and thus render less dangerous the delay before operation. My Case 128 of sarcoma was a case in which *x*-rays were first used for this purpose.

CHAPTER XVI.

PSEUDO-LEUKEMIA, LEUKEMIA, AND VARIOUS OTHER AFFECTIONS.

Hodgkin's Disease.—Hett * has reported a case of pseudo-leukemia of three years' standing, in a child aged twelve. The left cervical glands were very much enlarged, the spleen was enlarged, and there was marked cachexia. *X*-rays were applied for three weeks with disappearance of the enlarged glands. In a personal communication to me he states that there has been recurrence, but part of the improvement has been maintained.

Williams † has reported one case of pseudo-leukemia treated with *x*-rays, a young man who developed Hodgkin's disease with enlarged axillary and cervical glands and an enormously enlarged spleen. At the time of his report the spleen was much smaller and all of the glands had become softer, and most of them could not be seen or felt.

The first case of Hodgkin's disease treated by this method was the following case of mine:

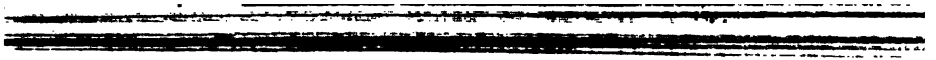
Case 148.—Child, aged four years, referred to me by Dr. A. J. Ochsner. The diagnosis of Hodgkin's disease had been made by Dr. Ochsner and Dr. Christian Fenger, as well as by others. The disease began in December, 1900, as a small hard swelling below the ears. The mother stated that every two or three days she could see more of the swellings appear. In May, 1901, the patient was in the Presbyterian Hospital under the care of Dr. Fenger, to whose aid I am indebted for most of the history. When the patient entered the Presbyterian Hospital the following notes were made: "Submaxillary, cervical, and supraclavicular lymph-glands are enlarged, hard, discrete. There are tense swellings, both anteriorly and posteriorly, especially on the left side of the neck. No other enlarged

* Dominion Med. Monthly, 1902, xix, p. 76.

† "Röntgen Rays in Medicine and Surgery," p. 675.

Fig. 166.—Pseudo-leukemia.

Fig. 167.



lymph-glands are found." The blood count showed 4,300,000 reds and 10,000 whites. Hemoglobin 50 per cent.

Dr. Fenger dissected out two lymph-glands in the neck, and "the pathologist's report states that there is no evidence of tuberculosis in the gland and that the histology coincides with that of a pseudo-leukemia." The diagnosis of Hodgkin's disease was made and the patient discharged with a "statement to parent that little if anything can be done to relieve patient." In August, 1901, patient entered Augustana Hospital in Dr. Ochsner's service. The condition of the swellings at that time is indicated in the following note: "A large, irregular swelling on the right side of the neck, size of a small fist, extending from below and behind the right ear to the clavicle. Numerous hard masses, varying in size from a filbert to an English walnut, can be felt. Small swellings of the left side of the neck about half the size of that on the right. The swellings are not tender, painful, or red, and are freely movable. No enlargement of liver or spleen." The diagnosis of Hodgkin's disease was made and Dr. Ochsner dissected out a large mass of glands on the right side of the neck.

On September 11 he referred the case to me for exposures to *x*-rays. The condition then is shown in figure 166. There was a healthy scar on the right side of the neck and on the left side a swelling the size of a small fist, made up of a group of greatly enlarged glands. They were hard, painless, and freely movable. These glands were put under exposures to the rays on September 11. In the course of a month erythema was produced and the glands rapidly diminished in size. At the end of two months there remained three or four small glands on this side of the neck which were quite soft and not larger than a filbert. Almost all the swelling had disappeared and the slight swelling that remained was as soft as adipose tissue. The condition at that time is shown in the accompanying illustration (Fig. 167).

There had been correspondingly great improvement in the general physical and mental condition of the patient. He had been changed from a cachectic, sluggish child, to a bright lively one. The number of red and white blood-corpuscles had re-

mained about the same, but there had been an increase in the hemoglobin to 80 per cent. as compared with 50 per cent. at the beginning of treatment. After the middle of November he had very desultory treatment. On January 28, 1902, after he had been given a few prophylactic treatments, the following notes were made: "Glands in the neck not bigger than peas. One or two inguinal and axillary glands about the size of a filbert. Epitrochlears not palpable." On April 22, after the treatment had been neglected for three months, he returned with the glands on the left side of the neck hard and about half as large as they were when I first saw him. Between April 22 and June 10 he had fifteen exposures over the cervical glands, with disappearance of the swelling. On June 2 the following note was made: "Masses on left side of neck entirely softened, except a portion the size of a large pea, which remains hard. Right side of neck free from any swelling or palpable glands." The blood examination at that time showed:

R. B. C.	4,096,000
W. B. C.	5000
Hemoglobin	53 per cent.

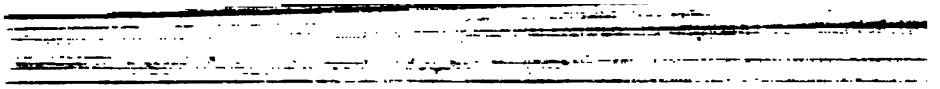
After that time he received ten exposures between June 13 and July 28. Then his parents discontinued the treatment and I did not see him again. There was a recurrence of the glands in the neck, for which an operation was done the last of October, and a few days later he died of inspiration pneumonia.

Case 149.—Man, aged fifty, referred to me by Dr. L. L. McArthur. The patient had typhoid fever five years before, but aside from that had no serious illness since childhood. In childhood he had an attack of inflammatory rheumatism, otherwise his personal and family history are negative.

In April, 1900, he noticed a swelling under the right arm and another on the inside of the elbow. These gradually increased in size, and in October, 1900, he consulted Dr. D. N. Eisendrath, who found, in addition, enlarged glands in the neck, in the other axilla, in the groins, and along the side of the abdomen. The case was seen in consultation by Dr. Christian Fenger, who agreed with Dr. Eisendrath in the diagnosis

Fig. 168.—Pseudo-leukemia.

Fig. 169.



of Hodgkin's disease. The diagnosis of Hodgkin's disease was also made by Dr. E. J. Dohring and Dr. M. L. Goodkind. The blood examination made at the time that Dr. Eisendrath saw the case showed 80 per cent. hemoglobin, 5,000,000 red corpuscles, and 10,000 whites.

Previous to beginning treatment with *x*-rays the patient had for a long time been taking arsenic, and for several weeks had been having parenchymatous injections of arsenic into the tumors. In spite of this treatment the glands had not decreased. The patient's general health had failed and he showed marked cachexia.

The size of the tumor in the right axilla when *x*-ray treatment began is shown in figure 168. It was about as large as a child's head and interfered seriously with the movement of the arm. The right epitrochlear gland was almost as large as a goose-egg. Its vertical diameter was four inches and its transverse diameter was about two and one-half inches. Both of the glands were movable but densely hard.

At Dr. McArthur's suggestion I began daily exposures over the right epitrochlear gland November 19, 1901, while he continued the parenchymatous injections of arsenic in the axillary gland. By December 18 I had produced considerable erythema over the elbow and the gland was reduced to less than half its previous size. In the mean time the axillary gland, which was having injections of arsenic, showed no change. These injections were then stopped, and at Dr. McArthur's suggestion I began exposures also over the axillary glands. The exposures over the epitrochlear gland were continued, and by January 1, 1902, all apparent swelling had disappeared and only a soft gland the size of a filbert was left. By January 7, after fifteen sittings, and upon the development of considerable erythema, the axillary gland had become quite soft and very much reduced in size. By January 20, all of the axillary swelling had disappeared. The condition of the axilla at that time and as it has remained for a year is shown in figure 169. There was very slight puffiness at the site of this tumor, but it was as soft as the softest adipose tissue. The man's general physical condition has been greatly improved. Dr. M. L. Good-

kind, who saw the patient after an interval of several months, particularly called my attention to the improvement in his general condition, which he characterized as astounding.

The patient was discharged January 20, 1902, and told to report occasionally; to report immediately if any enlarged glands developed. On September 16, eight months later, he returned with enlarged glands in the left groin, the left axilla, and the left side of the neck, the largest about the size of an English walnut. This change he had noticed first a few days before. He had also begun to run down somewhat physically. Under sixteen exposures between September 16 and October 17 all of the glands disappeared without the development at any time of more than slight erythema. He was also feeling very much better physically than when he returned for treatment. He remains well.

During the first period that this patient had *x*-ray exposures he also had the free use of arsenic, and it was a question as to how much of a factor the arsenic was in the reduction of the glands. During the last period of treatment he was given no arsenic, or other medicine, so that all factors except *x*-rays were ruled out. The result in this case is a very positive one. When he began treatment in November, 1901, he had been so run down in health for several months that he had been unable to attend to business. Since the first of January, 1902, he has felt as well as he ever did and has vigorously pursued an exacting occupation. There has been no interruption in his work in the entire eleven months.

Case 150.—Child, aged six years, referred to me in the last stages of cachexia from pseudo-leukemia. There were large masses in various parts of the body. He had thirteen moderate exposures without the production of an erythema and without effect, and treatment was discontinued by the patient. There was no effect upon the tumors, but not enough reaction was produced to expect any effect, and the case is, I think, of no weight.

I have treated one other case in which a diagnosis of probable Hodgkin's disease was made.

Case 151.—Miss ———, aged twenty-one. In March, 1902,

after a month of lassitude, the patient went to bed with what was thought to be typhoid fever. In May, 1902, she came to Chicago, and a diagnosis of probable Hodgkin's disease was made by Prof. Robert H. Babcock, of the University of Illinois, and by others. At the time that she was referred to me there was a group of three or four hard glands the size of a small olive on the right side of the neck above the inner end of the clavicle. There was a gland the size of an olive under the border of the pectoral muscle in the left axilla, and a gland the size of a filbert at the outer side of the elbow. Blood examination showed:

R. B. C.	3,208,000
W. B. C.	4200
Hemoglobin	63 per cent.
Small mononuclears	35 per cent.
Large mononuclears	4 per cent.
Polymorphonuclears	58 per cent.
Eosinophiles and a few poikilocytes	3 per cent.

Many small mononuclears showed distinct chromatin network in the nucleus, with a faintly stained non-granular margin about the nucleus in a few. Nuclei eccentrically placed.

During the previous two months the patient had a very low grade of fever, but in the last two weeks had improved considerably. Between July 2 and July 21, 1902, she received nine fairly strong exposures, with the production of a slight erythema. By July 21 all of the glands had disappeared, and the patient remains well at the present time.

It must of course be remembered that the tumors in pseudoleukemia disappear spontaneously at times, and in Case 151 I think that this factor of spontaneous disappearance of tumors cannot be excluded. But in Cases 148 and 149 any simple coincidence between the disappearance of the glands and the *x*-ray exposures can be clearly ruled out. In neither of these cases, after a year and a year and a half respectively, had any tendency to spontaneous disappearance of the glands shown itself, and there was no acute disturbance of the health at the time that these cases were under *x*-ray treatment to precipitate the subsidence of the glands. The sequence of the exposure

to the *x*-rays and the subsidence of the glands was as close and direct as possible. In each instance evidence of the effect on the glands began to show itself just before the corresponding effect upon the skin was produced, and this phenomenon was seen in a sufficient number of instances to mathematically rule out the possibility of coincidence.

Leukemia.—I have treated two cases of true leukemia with *x*-rays.

Case 152.—Mrs. ———, aged fifty, referred to me by Dr. A. J. Ochsner. The patient had a spleen filling all the right side of the abdomen, but without other glandular involvement, and the blood examination showed:

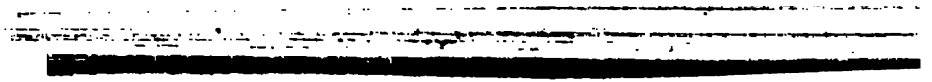
R. B. C.	3,000,000
W. B. C.	300,000
Hemoglobin	50 per cent.

She was given *x*-ray exposures for a month with no effect whatever. The exposures, however, were not carried to the point of producing any effect on the skin, and in my judgment the case shows nothing.

Case 153.—Man, aged forty-four, referred to me by Dr. Jacob Frank, of Chicago. The family and personal history of the patient were negative. In March, 1901, the present illness began with a chill, followed by a fever lasting two days. He felt well until a month afterward, when he had an exactly similar attack. On June 15, 1901, he had a third chill, followed by fever, and on the third day of this attack a large swelling, hard and red, appeared on the left side of the neck, causing constant pain. This swelling was incised on June 20 without finding pus. A week later, under hot dressings, a small amount of pus was discharged. After this he had several small abscesses in various parts of the neck. Early in September, 1901, a swelling the size of a man's fist appeared in the left axilla, which was removed surgically, and later swellings appeared again in the left axilla and in both groins. Within the last month the tumors in the right cervical and axillary regions had decreased in size somewhat. For about two months the patient had been hoarse. His condition at the time he came

Fig. 170.—Leukemia.

Fig. 171.



to me March 6, 1902, is shown in figure 170. In the right axilla there was a mass of five or six glands varying from the size of a walnut to larger than an egg. On the right side of the neck there was a very large mass of glands, ten or twelve in number, the largest the size of a small egg. All were freely movable, fairly hard, and painless. The circumference of the neck just under the chin was eighteen inches. In either groin there were masses of glands the size of a walnut and smaller, not freely movable, but painless. The liver was palpable in the parasternal line 10 cm. below the costal margin, the edge sharp, firm, and not tender. Greatest enlargement in left lobe. The spleen was distinctly palpable 8 cm. below the costal margin, the edge hard, round, and not tender. The diagnosis of leukemia had been made by Dr. Jacob Frank, Dr. Frank Billings, and others. He was cachectic to the last degree.

Between March 1 and March 25, 1902, he received eighteen fairly vigorous exposures with the development of slight dry dermatitis, and the marked subsidence of the exposed glands. A few days after the last exposure he was attacked with an acute illness which resembled, his physician stated, a miliary tuberculosis. On the morning of the first day of his illness he found that the glands which had been noticeable the night before in his neck had disappeared. When he returned after his illness on May 7, 1902, the glands had almost completely disappeared, as shown in figure 171. The glands on the left side of the neck had entirely disappeared. In the right axillary and cervical regions one gland in each remained; these were of the size of a lima bean and quite soft. The inguinal glands were soft and small, the largest the size of a hazelnut. The spleen was softer and smaller, reaching 6 cm. below the costal margin. The liver remained as large as on previous examination. After this his general physical condition improved very much. He was able to go away for the summer and take a long journey without overtaxing himself. In the middle of June blood examination showed a considerable improvement. September 6 he returned with a new group of enlarged glands on the right side of the neck and in the right axilla, for which he received four strong exposures, that were followed by the

disappearance of the glands. A few weeks later, however, they began to increase rapidly, and the patient died in the middle of November, 1902, in an acute, apparently septic attack, such as he had had from the beginning of the disease. There seems little reason to doubt the direct effect of *x*-ray exposures upon the glands in this case. The disappearance of tumors was in close sequence with the *x*-ray exposures, and they had never disappeared in the fifteen preceding months of his illness. The patient was not willing to have as persistent treatment as Dr. Frank and I thought he should have and his treatment was recognized at the time as inadequate.

The blood-counts in this case at different times were as follows:

	MAR. 6, 1902.	APRIL 9, 1902.	SEPT. 6, 1902.
Red blood-corpuscles	2,768,000	2,160,000	2,480,000
White corpuscles	74,300	12,000	102,700
Hemoglobin	45%	43.0%	48.0%
Polymorphonuclears	14%	41.1%	15.6%
Large mononuclears	5%	4.2%	0.8%
Small mononuclears	80%	53.3%	81.8%
Eosinophiles	1%	1.1%	0.3%
Mast cells		0.3%	
Nucleated reds	A very few	1.0%	1.3%
Non-granular polymorphonuclears			0.2%

The use of *x*-rays has been tried also in a few cases of numerous other affections. In some of these there have been logical indications for the use of the method; in others it has been tried empirically.

Neuralgias.—Stembo * has reported 28 cases of neuralgia, including all of the ordinary forms of that affection, which he has treated with *x*-rays. Of these 21, or 75 per cent., were promptly relieved. He found that relief usually followed three exposures.

Gocht † has reported the case of a man seventy-six years old who had suffered from trigeminal neuralgia of the right side for ten years, large doses of morphin being required to control

* Therapie der Gegenwart, 1900, N. F. ii, p. 250.

† Fortschritte a. d. Geb. d. Röntgenstrahlen, 1897, i, p. 14.

the pain. He applied for surgical treatment, but instead was treated daily with *x*-rays for half an hour. After the second day the patient had no more pain and required no more morphin. On the sixth day he had a very slight attack. Some time after the pain recurred, but to what extent is not known.

In view of the marked analgesic effect of *x*-rays on the pain accompanying malignant growths there is some ground for giving it a trial in intractable forms of neuralgia.

Rheumatism.—A number of writers have reported favorable effects of *x*-rays in relieving the pain of rheumatism.

Sokolow * has reported four cases: Case 1, a girl nine years of age, with articular rheumatism of the hands and knees accompanied by severe pain and pronounced swelling. The pain vanished after two exposures. In two other similar cases the pain disappeared after one and four exposures respectively. Case 4, a girl thirteen years old, with chronic rheumatism accompanied by severe pain and swelling of the knee, was greatly improved under *x*-ray exposures. Stenbeck † has reported fifty-two cases of chronic rheumatism treated by *x*-ray exposures. Forty per cent. were clearly improved; forty per cent. were subjectively better; twenty per cent. were uninfluenced. Escherich de Graz ‡ reports that "quite recently I have had occasion to note the very marked analgesic power of the *x*-rays upon the pain of a child suffering from rheumatic polyarthritis."

Pruritus.—The attempt has also been made to utilize the analgesic properties of *x*-rays in the treatment of pruritus.

Scholtz § has seen decided improvement result from the use of *x*-rays in a case of pruritus vulvæ, and Sjögren and Sederholm ‖ have reported the relief of pruritus vulvæ in seven cases which were given *x*-ray exposures.

The effect of *x*-rays in relieving itching is unquestionable, and the method deserves a trial in the treatment of the intract-

* Russky Vratch, 1897, No. 46; Abstr. Fortschritte a. d. Geb. d. Röntgenstrahlen, 1898, i, p. 209.

† Fortschritte a. d. Geb. d. Röntgenstrahlen, 1898, ii, p. 227.

‡ Révue des maladies de l'enfance, 1898, xvi, p. 242.

§ Arch. f. Derm. u. Syph., 1902, lix, p. 421.

‖ Fortschritte a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.

able cases of pruritus vulvæ and ani, as well as in the inflammatory dermatoses accompanied by intractable itching.

Goitre.—Williams * has reported improvement in a case of exophthalmic goitre treated with *x*-rays, and Campbell † has reported the improvement of a simple goitre in a patient who was having exposures for acne.

Brook, ‡ on the other hand, has reported the case of a patient who had carcinoma of the breast and a goitre, which was exposed, together with the carcinoma, to the *x*-rays. The carcinoma was symptomatically cured while the goitre was unaffected.

My experience in goitre includes three cases which have had fairly vigorous treatment:

Case 154.—An exophthalmic goitre which, after moderate exposures, showed no result.

Case 155.—A simple goitre, after vigorous exposures extending over two and a half months and carried to the point of producing marked pigmentation, showed no effect.

In another patient who had a goitre on one side that was exposed persistently to *x*-rays while a carcinoma of the breast was being treated (Case 80) there has been considerable diminution in the size of the goitre.

That *x*-rays will prove of benefit in goitre is yet to be determined. Nevertheless the results in glandular hyperplasias and in some cases of scar tissue yet to be referred to are sufficiently positive to give ground for a further trial of the method in goitre.

Scars.—Theoretically the use of *x*-rays would hardly be expected to be effective against healthy scar tissue, since it has practically the same powers of resistance as normal tissue. A marked favorable effect, however, has been observed upon the unhealthy scars of lupus which have been treated with *x*-rays, and as a result its use for the removal of scars has been suggested by Ullman§; and Hahn and Albers-Schönberg, ‖ Tay-

* "The Röntgen Rays in Medicine and Surgery," p. 679.

† Jour. Am. Med. Assoc., 1902, xxxix, p. 313.

‡ Brit. Med. Jour., 1902, ii, p. 1303.

§ Wien. med. Presse, 1900, xli, p. 954.

‖ Münch. med. Wochens., 1900, xlvii, pp. 284, 324, 363.

lor,* and Harris † have reported the removal of scars by this method. This application of the method was suggested to me by the marked improvement in the apparently healthy scars of my Case 34 of lupus treated by *x*-rays, and I have used the method successfully in one very thick keloid:

Case 156.—Boy aged ten years, referred to me by Dr. D. A. K. Steele. A keloid formed several years ago on a vaccination scar, and another upon a scar on the helix of his left ear. These were removed and promptly recurred. The keloid on the arm (Fig. 172) was a typical keloid two and a half inches long, three-fourths of an inch broad, and at least half an inch thick. Each of the stitch scars around this showed a keloid about the size of a marrowfat pea. The keloid on the ear was a curious-looking globular tumor about an inch in diameter, purplish in color, with dilated blood-vessels coursing over it, and had grown rapidly. It resembled to an alarming extent a sarcoma. The *x*-ray exposures were begun over the keloid on the arm in December, 1900, but the patient's attendance was desultory, and with a moderate amount of treatment no effect was produced. It was not until after 80 exposures had been given, extending over seven months, that any effect was produced. In July and August, 1901, however, I carried the treatment to the point of producing a very acute dermatitis with the formation of a superficial necrotic membrane. This healed over in three weeks, and from that time, September, 1901, the keloid rapidly shrunk. It had practically disappeared by November 1, 1901. The difference at that time is shown in figure 173. The entire keloid had disappeared except for a slight ridge down the center of the scar. It seemed to me two or three months later without further treatment that there was a slight tendency toward thickening of the keloid, and I was apprehensive of the recurrence of the growth. Since September, 1901, however, this lesion has had practically no treatment, and, contrary to my apprehension, it has steadily improved, so that at the present time there is no thickening of the tissue left. The little ridge that extended down the center has disappeared and the whole

* Brit. Med. Jour., 1901, ii, p. 853.

† Australasian Med. Gazette, 1901, xx, p. 133.

area is soft and pliable and thin (Fig. 174). This steady improvement for a year seems to give good grounds for expecting a permanent success.

The keloid on the ear (Fig. 175) has been on two occasions exposed to *x*-rays to the point of producing a marked vesicular dermatitis, with the result that it has shrunk to about one-half its previous size (Fig. 176). It is still under somewhat irregular treatment and there seems good reason to expect a successful result.

Judging from the result in this case, no scar tissue is too well developed to render success impossible, and the method should be given a persistent trial in such cases. The fact that results were not gotten in this case from six months of moderate treatment and then were obtained by vigorous pushing of the exposures is instructive.

Elephantiasis.—Mascat * showed at the Academy of Science, Paris, February, 1898, a series of photographs of a patient suffering from elephantiasis who had recovered under a few *x*-ray exposures.

Callous Sinuses.—Hart † has reported a case of abdominal sinus five to six inches long, which had refused to heal after several weeks of gauze plugging, and which after an exposure for *x*-ray photograph cicatrized almost immediately. A second case where sinuses had existed for months was given three exposures with prompt healing.

Chronic Ulcers.—Sjögren and Sederholm ‡ have reported four cases of sluggish indurated ulcers which had resisted ordinary methods of treatment and which healed under the stimulation of *x*-ray exposures.

I have seen similar beneficial results from *x*-ray exposures in several indolent ulcers, including one varicose ulcer. In chronic indolent ulcers doubtless *x*-ray exposures may be valuable in furnishing the stimulation that is at times a necessary part of the treatment of such lesions.

Nævus.—The removal of hair from hairy nævi was successfully

* Lancet, 1898, i, p. 544. † Brit. Med. Jour., 1902, i, p. 1330.
‡ Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.

Fig. 172.—Keloid. July, 1901.

Fig. 173.—November 1, 1901.

Fig. 174.—November 10, 1902.

Fig. 175.—Keloid.

Fig. 176.

accomplished by Freund * in his first case of hypertrichosis treated by this method.

I have treated one case of hairy nævus of the forehead of a young child with what bid fair to be excellent permanent results.

Case 157.—Child, aged two years, with a pigmented nævus on the forehead covered with a profuse growth of long, black hair. Under persistent treatment extending over six months the hair and almost all of the pigmentation and hyperkeratosis were removed, so that the skin is now smooth and soft and almost of normal color. The hair has been absent now for four months and shows no tendency to return. There is in my opinion little room for doubt that *x*-rays will furnish a successful method of dealing with many cases of pigmented and hairy nævi.

Vascular Nævi.—Jutassy † has given a very interesting report of the successful treatment of an extensive vascular nævus of the face. Over part of the area involved the nævus was flat, but on the cheek and nose there were dilatations forming angiomata from the size of a hemp-seed to that of a bean. The exposures in this case were carried to the point of producing a very acute dermatitis with free vesiculation. As a result the nævus was practically destroyed. There remained over the area a soft smooth scar of almost normal color. There was no trace of angioma left. A year and a half later the improvement had been maintained.

I have treated part of a flat vascular nævus of the face and neck by this method.

Case 158.—Miss ———. Exposures in this case were made experimentally over an area on the side of the neck the size of a silver dollar, and they were carried to the point of producing an acute dermatitis, upon the subsidence of which there was marked improvement in the color. This improvement has been maintained. The exposed area is much paler than the rest of the nævus and evidently a large number of telangiectases have been destroyed.

* Wien. med. Wochens., 1897, xlvii, p. 428.

† Pest. med.-chir. Presse, 1900, xxxvi, p. 73.

It is possible that by setting up an acute reaction in a vascular nævus there may be produced scar tissue that will be of such a character as practically to destroy the lesions. Of course, the likelihood of doing this is greater, the less the dilatation of the blood-vessels. It is almost surely true that where there are large angiomata the method will not be very effective, although Jutassy's case seems to show that it may be possible to deal with superficial angiomata.

Verruca.—Scholtz * and Sjögren and Sederholm † have reported the disappearance of warts under *x*-ray exposures without the production of marked reaction in the tissues. I have myself seen several warts disappear from the face while patients were having treatment for other purposes.

Clavus.—Zeisler in a personal communication has reported the disappearance of soft corns on the bottom of the feet under a few exposures. The case was one in which the development of keratoderma on the soles was so severe as to interfere very greatly with walking. Relief was complete.

Senile Verruca.—In considering the treatment of cutaneous carcinoma I have called attention to the cure of patches of senile keratosis on the faces of four patients (Cases 64, 66, 69, 70). In all of these cases several patches of senile keratosis were successfully treated. The results in these cases were ideal, and seem to indicate that in the use of *x*-rays we have found a much-needed method of successfully getting rid of these lesions. In these cases I have used the method not only in patches which showed beginning precancerous changes, but also in patches whose bases showed no evidence of inflammatory changes whatever. There has been manifest thus far in my cases no tendency whatever to recurrence of the senile patches.

Leucoma.—Williams ‡ has attempted to remove scars of the cornea by exposing the cornea to *x*-rays. In one case of leucoma which he treated there has been considerable improvement in the patient's condition. The method is perhaps worthy of trial, but it is not in my opinion free from danger.

* Arch. f. Derm. u. Syph., 1902, lix, p. 421.

† Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, iv, p. 145.

‡ "The Röntgen Rays in Medicine and Surgery," p. 679.

CHAPTER XVII.

GENERAL CONCLUSIONS.

Non-malignant Diseases.—A consideration of the entire subject of radiotherapy in its present stage of development seems to leave no room for doubt that we have in it a valuable addition to the means at our command for combating disease. The method has more than justified its small beginnings five years ago, and at the present time it bids fair to revolutionize the methods of treatment of certain affections. One of the greatest values of the method lies in the fact that it is applicable to certain groups of diseases which have hitherto been classed among the most intractable with which we have to deal. This applies not only to its use in malignant diseases, but to its use in certain less grave affections which have been the trial and the bane of dermatology.

That the use of *x*-rays is a valuable addition to the methods at our command for treating hypertrichosis, acne, and sycosis there seems no question; and that in itself is no small gain to dermatology. Its use in tinea tonsurans and favus is less well established, but is unquestionably worthy of persistent trial. In the treatment of certain intractable forms of eczema, lichen planus, and psoriasis there seems good reason to believe that the method has a distinct field of usefulness. Its value in lupus erythematosus is not yet well established. Its value in lupus vulgaris is above question. This method and Finsen's method of treating lupus with ultra-violet light have inaugurated a new period in the treatment of that most intractable and distressing affection.

Were the entire field of usefulness of radiotherapy embraced in the treatment of the affections briefly referred to above, the agent would be an addition to our therapeutic armamentarium of no mean proportions. The above, however, takes no account of

its application on malignant diseases, in which unquestionably it has its greatest field of usefulness.

Malignant Diseases.—Upon such a topic as the value of *x*-rays or any other agent in the treatment of malignant diseases, conclusions must be drawn with the greatest reservation, but with the experience now at our command certain facts may be said to be established.

First: Under the influence of *x*-rays alone, carcinomata can be made to disappear and can be replaced by healthy tissue. This is established not only clinically, but also by microscopic studies. Such a disappearance of a malignant growth is a new fact. It gives us a method of treating malignant growths essentially new in principle.*

The theoretical advantages which the method offers are:

(*a*) It is painless. It avoids the ordeal of operations, a fact of importance for a large number of the patients of this class.

(*b*) Under proper conditions it destroys diseased tissue but leaves the healthy tissue in its place. Accordingly,—

(*c*) It leaves small scars, and—

(*d*) It can be used in cases where the surrounding healthy tissue cannot be sacrificed. This means that—

(*e*) It is valuable in certain cases in which ordinary methods are objectionable, because they involve extensive operations and serious subsequent disfigurement; as, for example, about the eye and nose. This means further that—

(*f*) It has a field of usefulness in cases in which ordinary methods are impossible, because of the amount of destruction of tissue which complete removal would require. In other words, it is applicable to some inoperable cases.

(*g*) It is not only painless, but it usually has a marked anodyne effect in painful malignant diseases.

The extent of application and the limitations of the method are not yet determined. In cutaneous carcinoma without

* In speaking of this method as essentially new in principle, the use of ultra-violet light must, of course, not be overlooked. That also is essentially new in principle, but it and *x*-rays, as I have previously undertaken to show, involve essentially the same therapeutic principle, so that wherever I speak of the use of *x*-rays in a connection where ultra-violet light might be used I mean to include it in my comparison or my statement.

metastasis the method has a list of well-established successfully treated cases, sufficient to give it standing in comparison with any other method of treating such lesions. Even for cases which are entirely amenable to ordinary methods of treatment, such as small epitheliomas, the method may challenge comparison of its results with those obtained in any other way. It has the advantage of producing a minimum of scarring and thus giving cosmetic results that are unapproachable by any other method.

In inoperable growths upon the surface the method has a very considerable number of not only brilliant but amazing results to its credit. These results have been attained not only in growths which are entirely on the surface, but in numerous cases the results establish the fact that the effect may be obtained several inches beneath the surface; as, for example, Cases 75, 95, 97, 98, 119, 128, 132, 148, and 149 in my list. As to the effect upon malignant growths which involve the cavities of the body, the standing of the method is not yet established. There are some facts which give us reason for encouragement in these cases. Pain can be controlled, and there is reason to believe that in some cases—as, for example, Cases 104 and 121 in my list—malignant growths situated in the cavities of the body can be checked in their course and perhaps reduced in size by the methods of applying *x*-rays already at our command. And the results in some cases, including a few cases in the cavities of the body, as my Case 119 with carcinoma within the cranium, have been so surprising that they give encouragement for the persistent trial of this method in the most desperate cases. This is the more true because in the cases which we are now considering the method is not poaching upon the preserves of any other method of treatment that offers any hope of relief of any sort. These are cases which have been hitherto entirely beyond hope.

When we come to the treatment of operable malignant growths the responsibility for advocating the use of *x*-rays becomes greater. In cutaneous carcinomata there are good grounds for the advocacy of *x*-rays in place of other methods of treatment. The method has advantages which in my opinion

entitle it to rank as the method of preference in the treatment of epitheliomata. When it comes to more extensive forms of operable malignant growths, particularly growths where the dangers of metastasis are imminent, and therefore the question of time very important—as, for example, in carcinomata of the breast—the situation is different. Our experience with *x*-rays is not sufficient to warrant us in relying upon this method alone in such cases. Were the results of surgical intervention in such cases better, the advocacy of *x*-rays as a substitute would certainly not be justified; but even unsatisfactory as they are, we are not justified in refusing to avail ourselves of the benefits which surgery offers in suitable cases. This is the more true because by availing ourselves of surgery, we are not cut off from the use of *x*-rays at the same time.

Prophylactic Use of X-rays.—On the other hand, I believe the argument for operation in suitable cases is no stronger than the argument for the use of *x*-rays in conjunction with surgery in these same cases, and that with the present knowledge before us the man who operates and refuses to avail himself of the advantages of *x*-rays is in as illogical a position as the man who uses *x*-rays in such cases and refuses to avail himself of the possible benefits of operation. The combination of the two methods of treatment may be logically claimed in my opinion as the proper procedure in cases which are suitable for operation. With the fact before us as to the effect of *x*-rays upon palpable malignant infiltrations, the use of *x*-rays as a means of prophylaxis subsequent to operations for malignant growths may be urged as a necessary measure, if patients are to be given the best possible chance of escaping recurrence.

Use of X-rays Preliminary to Operations.—The use of *x*-rays may be urged also as a method of preliminary treatment of malignant growths when for any reason, as while waiting to get a patient in condition, it is necessary to postpone operation. There are good reasons to hope that by such preliminary exposures many malignant growths may be checked in their course, so that the patient under exposures would not be losing ground while waiting for operation.

Permanency of Results.—As to the permanency of the results

produced by *x*-rays, our experience is not sufficiently long to justify any dogmatic claims. In epithelioma I am willing to hazard the opinion, from the character of the scars, that the results will not show an undue proportion of recurrences. As to the permanency of results after the symptomatic cure of inoperable malignant growths, or growths which offer large possibilities of metastases, it would be manifestly absurd for any one to make dogmatic claims for either this method or any other.

Length of Treatment of Successful Cases.—The question naturally arises as to how long treatment should be continued after apparent cure of these growths. In favorable cases of epithelioma, cases in which every point of the scar is above suspicion, it is not my practice to continue treatment after a healthy scar is obtained. All such cases, however, are if possible kept under frequent observation, as they would be after any other method of treatment. In all cases which are grave, or in which there is a likelihood of the development of metastasis, I advise the repetition of series of exposures, each series sufficiently long to cause evidence of reaction. For example, after a recurrent carcinoma of the breast has been symptomatically cured, it would seem advisable to have the treatment repeated at intervals for at least three years. It is generally assumed that a malignant growth cannot be accepted as cured until three years have passed after its disappearance without recurrence. It would seem a necessary corollary of that assumption, then, that prophylactic treatment for the prevention of recurrence should be continued for at least three years. The proper procedure would seem to be to give a series of exposures at least two or three times a year, the exposures to be carried to the point of producing a reaction. By such a course we have the best chance of destroying any budding focus of disease before it has amounted to a palpable recurrence.

Reasons for Different Results in Similar Cases.—The question naturally arises as to the reason for the different results in similar cases of malignant growths, and one is led to speculate at once as to whether there is not a difference in susceptibility

to *x*-rays of different forms of carcinoma and sarcoma. There are no data available at present upon this subject. The knowledge of the histological character of the cases that have been treated is too meager to allow of any deductions upon this point. Were the material available from which to make a study of the relative susceptibility to *x*-rays of different forms of malignant growths, it is likely that highly interesting facts would be discovered. The explanation of the difference in susceptibility to *x*-rays in different cases of malignant disease will be found, in my opinion, to depend upon two facts: first, the difference in susceptibility of different forms of malignant growths and second, a similar difference in susceptibility of different individuals.

Effect of X-ray Exposures on General Health.—The improvement in general health of patients with malignant growths under treatment with *x*-rays is a notable fact in many cases, and is the best possible evidence of the radical effect upon the disease. A marked improvement is seen in many cases, and is usually observed when the malignant tumors are subsiding under *x*-ray exposures. This goes very far to refute the statement that it is dangerous to cause a rapid absorption of a large malignant growth, on account of the danger of toxemia from absorption of the products of this destructive process. In the many cases of malignant disease in which I have observed the rapid disappearance of tumor masses I have never seen any suspicion of acute toxemia. A few patients, however, have complained of articular rheumatic pains while tumors were subsiding, and this has occurred with sufficient frequency to lead me to suspect that perhaps it was in part due to the presence in the system of the products of degeneration. Other observers have called attention to the same fact. Aside from this altogether insignificant trouble, I have never seen any effect that might be attributed to intoxication. And nothing has happened in my experience to lessen my desire to cause the destruction of these tumors as quickly as possible. As a rough guess, I should say this complaint of rheumatic pains has occurred in less than 5 per cent. of the cases in which I have seen large masses of malignant growths subsiding under *x*-ray exposures.

Sterne * has reported a case in which there was an acute toxemia resembling an acute sepsis that he thinks was due to the liberation of toxins in the destruction of large masses of glandular tissue. The case was one of enormous enlargement of many glands, probably a leukemia or a pseudo-leukemia. Under *x*-rays the enlarged glands decreased until they had disappeared altogether. The spleen and liver enlarged, the spleen finally reaching down to the rim of the pelvis. With the disappearance of the tumors the apparently septic condition developed. The patient finally passed into coma. "Convulsions set in, and he died with every mark of violent sepsis, not only clinically but microscopically, demonstrable through blood changes."

One of my cases of leukemia, which is described in detail on page 552, had a similar attack after the subsidence of his glands under *x*-rays, but he had the same sort of attacks before ever coming under *x*-rays, and he died in such an attack at a time when he had not been having *x*-ray exposures for six weeks, and when there was no reasonable ground for believing that his attack had any connection with any toxic substances liberated in the disappearance of his tumors under *x*-rays. The evidence in these cases, therefore, is not conclusive, and there are no other cases in the literature which justify the assumption that an acute toxemia can be produced by the absorption of products set free in the disintegration of tumor masses under *x*-ray exposures. I have had numerous opportunities of seeing large masses of carcinoma and sarcoma disappear under *x*-ray exposures and have never seen any symptoms of an accompanying acute toxemia.

Effects on the Blood.—Friend,† in a preliminary note, has reported that: "While treating patients with the Röntgen rays, I observed in a case of inoperable cancer of the breast and in a case of intra-abdominal sarcoma, as one of the effects of treatment, a great increase of erythrocytes and a great diminution of leucocytes."

I have examined the blood in a number of cases of malignant

* Indiana Med. Jour., 1902, xxi, p. 56.

† American Medicine, 1902, iv, p. 11.

growth which were subsiding under *x*-ray exposures without finding any peculiar characteristics. The erythrocytes have been counted in at least a dozen cases of carcinoma, and in two or three cases of sarcoma. There has always been some diminution in the erythrocytes, and never a marked increase. The diminution has been such as would be expected in patients in the physical condition that these patients usually present. I have made differential counts of the white blood-corpuscles in several cases of carcinoma, in which at the time tumors were subsiding under *x*-ray exposures. None of these counts has shown anything unusual.

Coley * has also made a count of the red blood-cells and a differential count of the white cells in three cases of sarcoma when the tumor was decreasing in size under *x*-rays. His counts also show nothing unusual. Coley's findings and mine, therefore, discover no peculiar changes in the blood while malignant tumors are being absorbed under *x*-ray exposures, and do not confirm the increase in the red cells and the decrease in the whites which Friend found in his case.

Danger of Metastasis Under X-ray Exposures.—It has also been suggested that in the treatment of a malignant tumor with *x*-rays the danger of the development of metastases may be increased on account of the reaction produced by the *x*-rays. Were the inflammatory process produced by *x*-rays in a mass of carcinoma, for example, a simple inflammatory process, there would be more grounds perhaps for this fear. But this is not the situation; in the first place, it is not necessary to get up a marked inflammatory reaction in order to destroy the carcinoma cells in most instances; and, in the second place, when a marked reaction is produced, this is not a reaction accompanied by exuberant growth of the carcinoma cells as a result of increased blood-supply. On the contrary, when such a reaction is produced in a mass of carcinoma cells, there is not only not created a favorable situation for the growth of the carcinoma, but there is created a situation of which the most salient characteristic is the destructive process that takes place in these cells. The two characteristic histological changes

* American Medicine, 1902, iv, p. 251.

of the process are degenerative changes in the cells of the malignant tissue—this change beginning, too, in the youngest cells at the periphery—and obliterative endarteritis of the vessels of the part, certainly not changes that are conducive to the proliferation of the growth. It is hard to see how a process which readily destroys carcinomatous tissue in this way can at the same time render the danger of proliferation greater. The clinical data at our command are not sufficient to furnish any evidence upon this point, but as far as they go they lend no weight to the suggestion. Upon theoretical grounds alone there is, in my opinion, every reason to believe that the process of destruction by *x*-rays of masses of carcinoma or sarcoma lessens very much, rather than increases, the dangers of metastasis.

Use of Other Treatment in Conjunction with X-rays.—Of course, there is no objection in the treatment of malignant growths or other troubles with *x*-rays to the use of other methods of treatment in conjunction with *x*-rays. In my early use of *x*-rays, before the method's value was established, I avoided as far as possible all adjuvants, but at the present time everything possible is done to help along the recovery. As for local treatment, the cases are given ordinary surgical dressings. It is not necessary to be as careful of these dressings as under ordinary circumstances, because while under *x*-ray exposures the ulcers almost of themselves remain sterile. There would be, of course, no objection to the use along with *x*-rays of curetting or caustics, or other such methods of treatment, were they necessary; but in no case have I found the aid of such methods necessary. In one or two cases small recurrent or remaining nodules of carcinoma have been destroyed by me with caustics simply for convenience. As to internal treatment, the patients have been taken care of along ordinary lines. In all but superficial carcinoma it is my practice to give the patients sodium cacodylate as freely as they can tolerate it, for the reason that there seems some ground to believe that this has an inhibitory effect upon the growth of carcinoma, but no further specific medication has been given in any case except where it is mentioned in the recital of the cases.

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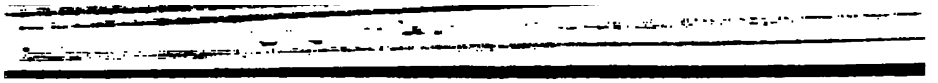

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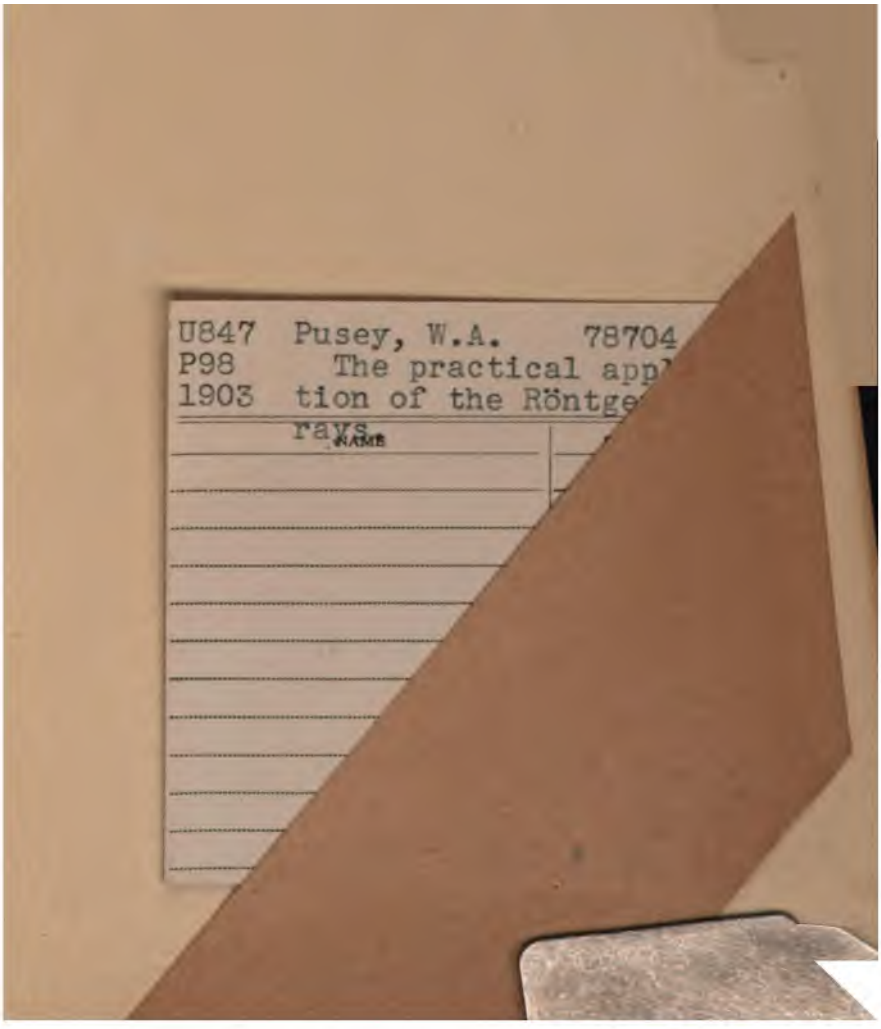
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